Feasibility Report

Dredging of PCB-Contaminated River Bed Materials Upper Hudson River, New York

For
New York State Department of
Environmental Conservation
Albany, New York

Volume 2 — Engineering Studies

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CONSULTING ENVIRONMENTAL ENGINEERS

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CHAPTER I

INTRODUCTION

This report evaluates the feasibility and cost of dredging PCB-contaminated bed materials from the Upper Hudson River, between the Federal Dam at Troy and Lock 7 at Fort Edward.

This introductory chapter contains four sections:

- Purpose and Scope of Report
- Background
- Study Area
- Report Organization

Purpose and Scope of Report

This report has been prepared to assist the Commissioner of the New York State Department of Environmental Conservation (DEC) in fulfilling the requirements of the PCB settlement of September 8, 1976, to "further investigate the need for remedial action concerning PCB's present in the Hudson River [and] implement such remedial action, if necessary to protect the public health and resources..."[1]*

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*References appear at the end of each chapter.

Specifically, this report considers one possible solution to the problem of PCB-contaminated bed materials in the Upper Hudson, that is, the removal of such materials by dredging and their disposal by long term containment. The report evaluates the cost, performance and environmental impact of alternative dredging systems and recommends a specific, feasible dredging program.

In addition, this report will serve as a basis for the preparation of an Environmental Impact Statement, should such a statement be required under the provisions of the State Environmental Quality Review Act (SEQR).

Malcolm Pirnie, Inc., was assisted in the preparation of this report by Gahagan & Bryant Associates, who participated as a subcontractor. Gahagan & Bryant's work was in the areas of dredging feasibility and technology, and dredging cost estimates.

Implementation of the dredging program will be contingent upon consideration by the DEC of all aspects of the PCB problem including this report and the findings of other, concurrent, investigations.

Background

Polychlorinated biphenyls (PCB) are one member of a class of synthetic chlorinated organic compounds composed of two, six carbon ring structures (phenolic rings) with ten possible chlorine attachments. PCB has ideal chemical properties for a number of industrial uses including dielectric fluids in transformers and capacitors, hydraulic and heat transfer fluids, plasticizers, adhesives, printing products and paper coatings. However, PCB is also highly toxic and has been shown to cause harmful effects in numerous animal species, including man.

In New York State, PCB has been used at Hudson Falls and Fort Edward capacitor manufacturing facilities on the Upper Hudson River. In 1975, the United States Environmental Protection Agency (EPA) and the Fish and Wildlife Service analyzed samples of fish taken from the river and found that PCB concentrations were substantially higher than FDA limits. Legal proceedings brought by DEC resulted in a finding that both the General Electric Company and the state and federal regulatory agencies were at fault in allowing the PCB discharge. A settlement was subsequently reached, which called for General Electric to cease using PCB by July 1977. In addition, the DEC is to investigate the need for remedial action concerning PCB already in the Hudson and General Electric is to contribute $3 million to the State as its share of such work.

As a result of this settlement the DEC has initiated a comprehensive program of mapping, sampling, monitoring, engineering studies and computer simulation of which this report is one part.

Study Area

The study area for this report is the Upper Hudson River, and adjacent lands, between the Federal Dam at Troy, New York and Lock 7 at Fort Edward, New York. The drainage basin of this portion of the river is shown in Plate I.

The Hudson River from New York Harbor to Albany is a tidal estuary with a length of about 130 miles. Beginning at the Federal Dam at Troy just north of Albany, to Fort Edward, the river is a series of pools created by eight dams with locks for New York Barge Canal traffic. Navigational charts for the barge canal are presented in Appendix "A". The River in this reach falls 119 ft over a distance of 41 miles for an average fall of about 3 ft per mile. From the Fort Edward Dam site north to its junction with the Sacandaga River, the Hudson River is another series of pools formed by seven dams, which along with the three natural waterfalls, are used for the generation of hydroelectic power. The River in this reach falls 429 feet over a distance of 29 miles for an average fall of about 15 ft per mile.

The drainage area at Fort Edward at the head of the study reach is 2,818 sq mi. At Federal Dam the drainage area is 8,090 sq mi including 3,450 sq mi of the Mohawk River. Low flows in the study reach are regulated to approximately 3,000 cfs for navigation and hydropower generation. The minimum navigable depth maintained is 12 ft. Allowable barge tow dimensions in the Champlain canal locks are 43.5 ft by 300 ft. Minimum vertical clearance is 15.5 ft.

A plan and profile of the Hudson is shown in Plate II.

During July to October 1973, the Fort Edward Dam, located just upstream of the study area, was removed. Subsequent to the removal substantial quantities of debris and sediments, now known to be contaminated with PCB, were scoured from the former dam pool and were deposited in the study area, primarily in the east and west channels at Rogers Island. A substantial portion of these materials were removed by the New York State Department of Transportation (DOT) in 1974-75. In April 1976 the occurrence of a 100-year flood at Fort Edward caused scour and redeposition of substantial additional quantities of debris. At the present time the DOT is again removing about 200,000 cu yd from the east channel at Rogers Island for maintenance purposes. A more complete discussion of the conditions associated with the Fort Edward Dam removal and subsequent remedial measures are contained in the reports prepared for the DEC.[3,4,5]

Alternative Dredging Systems

Alternative dredging systems have been described and evaluated on the basis of four principal system elements:

- Data
- Dredge/Transport Systems
- Disposal Sites
- Return Flow Treatment

The elements and their relationships are indicated in Figure I-1.

Organization of the Report

This report is divided into three volumes:

Volume 1 - Summary

Volume 2 - Engineering Studies

Volume 3 - Environmental Assessment

This volume of the report is Volume 2 and is divided in eight chapters, as follows:

Chapter I - Introduction; gives a brief summary of the location and background conditions for the study.

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ALTERNATIVE DREDGING SYSTEMS

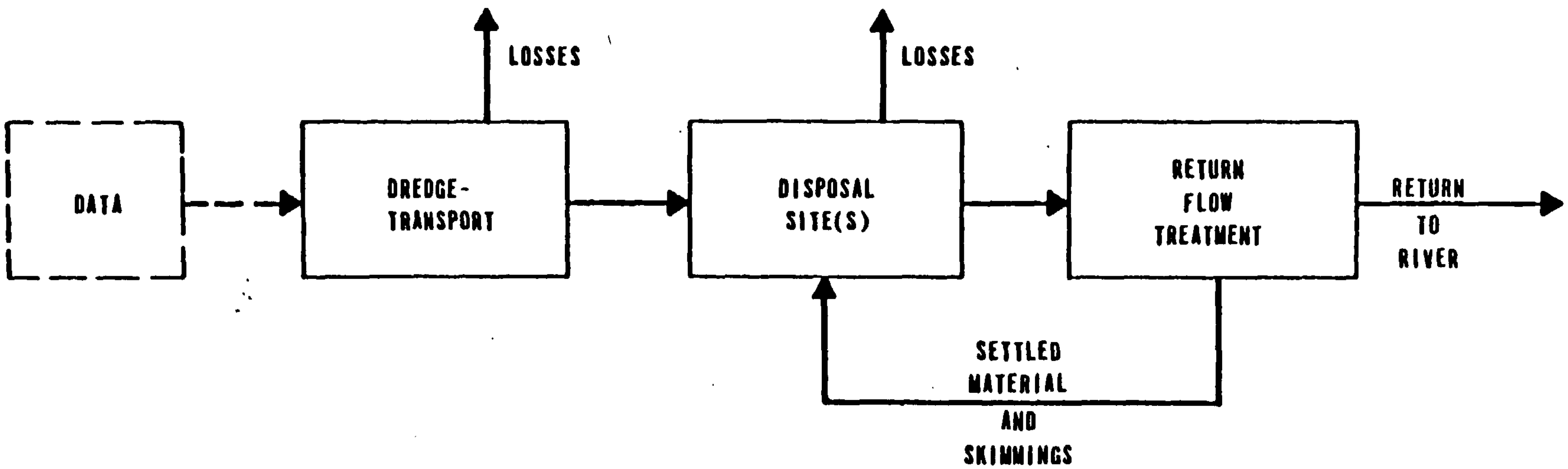


Figure 1-1

Chapter II - Existing Conditions; summarizes available data on river parameters, bed material quantity and characteristics, and PCB concentration in bed materials.

Chapter III - Dredging Technology; examines dredge and transport systems in terms of cost, performance, PCB removal efficiency, depth required, sediment types handled, and related considerations.

Chapter IV - Disposal Sites; discusses site selection criteria and describes potential dredge spoil disposal sites. Describes site selection and design procedures.

Chapter V - Return Flow Treatment; examines feasibility and cost of various methods for treatment of dredge return flow.

Chapter VI - Alternative Systems for Total PCB Removal; examines various dredging programs for removal of 24 in. of bed material over the study area.

Chapter VII - Alternative Systems for Partial PCB Removal; discusses criteria for partial removal and describes alternative systems to accomplish different levels of removal.

Chapter VIII - Findings, Conclusions and Recommendations; this chapter summarizes the findings and conclusions contained in this volume of the Feasibility Report, and presents recommendations drawn from these conclusions.

REFERENCES

CHAPTER I

1. Sofaer, A.D., NYSDEC, "In the Matter of Alleged Violations of Sections 17-0501, 17-0511, and 11-0503 of the Environemntal Conservation Law of the State of New York by General Electric Company, Respondent", Agreement (September, 1976)

2. Sofaer, A.D., NYSDEC, "In the Matter of ... by General Electric Company, Respondent", Interim Order and Opinion File No. 2833, Page 20 (February 9, 1976)

3. Malcolm Pirnie, Inc., "Investigation of Conditions Associated with the Removal of Fort Edward Dam", (1975)

4. Malcolm Pirnie, Inc., "Maintenance Dredging, Champlain Canal Fort Edward Terminal Channel, Fort Edward, New York", (1977)

5. Malcolm Pirnie, Inc., "Investigation of Conditions Associated with the Removal of Fort Edward Dam, Review of 1975 Report", (1977)

CHAPTER II

EXISTING CONDITIONS

Introduction

A considerable body of data has been accumulated concerning the existing situation on the Upper Hudson, including PCB in the water column and distribution in bottom materials, monitoring of dredge spoil areas, landfills and return waters, biological monitoring of both benthic macroinvertebrates and fish, and ground water sampling. In addition, Normandeau Associates, Inc., Bedford, New Hampshire, (NAI) carried out a bed material mapping and sampling program on the Upper Hudson, primarily during the spring of 1977, under contract to the DEC.

Data from bed material sampling programs earlier than NAI Spring 1977 are summarized and discussed in several sources[1,2] and will be discussed only briefly here. The NAI Spring 1977 data and the laboratory analysis of that data have only become available recently and are discussed in more detail.

Data Set 1 (DEC Fall 1975)

This data set consists of 26 bed material samples collected between August 27 and September 30, 1975. Five of the samples are within the study area. All the samples within the study area are surface grab samples, except for one core. This core, located at the Thompson Island Dam (RM 188.4) was 9-in. deep, and included one segment, between 3 and 4-in. deep, with a PCB concentration of 3,707 μg per g. This is the highest concentration ever measured in the study reach.

Figure II-1 shows a plot of PCB concentration versus river mile for Data Set 1. The concentrations plotted are an unweighted average of all PCB samples analyzed at each cross section, including both surface grab samples taken with a ponar sampler and core sections. The range of PCB values observed at each section is also given. Values greater than 800 μg per g are plotted at 800 μg per g and noted.

<u>Data Set 2 (DEC Winter 1976)</u>

This data set consists of nine bed material surface grab samples, collected between February 24 and March 4, 1976. PCB concentrations ranged from 0.4 μg per g at Bouy 119 below Schuylerville (RM 177.4) to 32.6 μg per g at the Route 129 bridge (RM 181.2).

A plot of PCB concentration versus river mile for Data Set 2 is presented in Figure II-2.

PCB CONCENTRATION VS RIVER MILE
DATA SET 1 (DEC FALL 1975)

NOTES:

1. I denotes maximum and minimum values observed at each river cross section.
2. ⁝ indicates an envelope of PCB concentrations defined by the range of concentrations at each cross section.
3. ——— indicates the unweighted average of PCB concentrations at each cross section.
4. PCB concentrations greater than 800 ug/g are plotted at 800 ug/g, with the actual maximum noted.

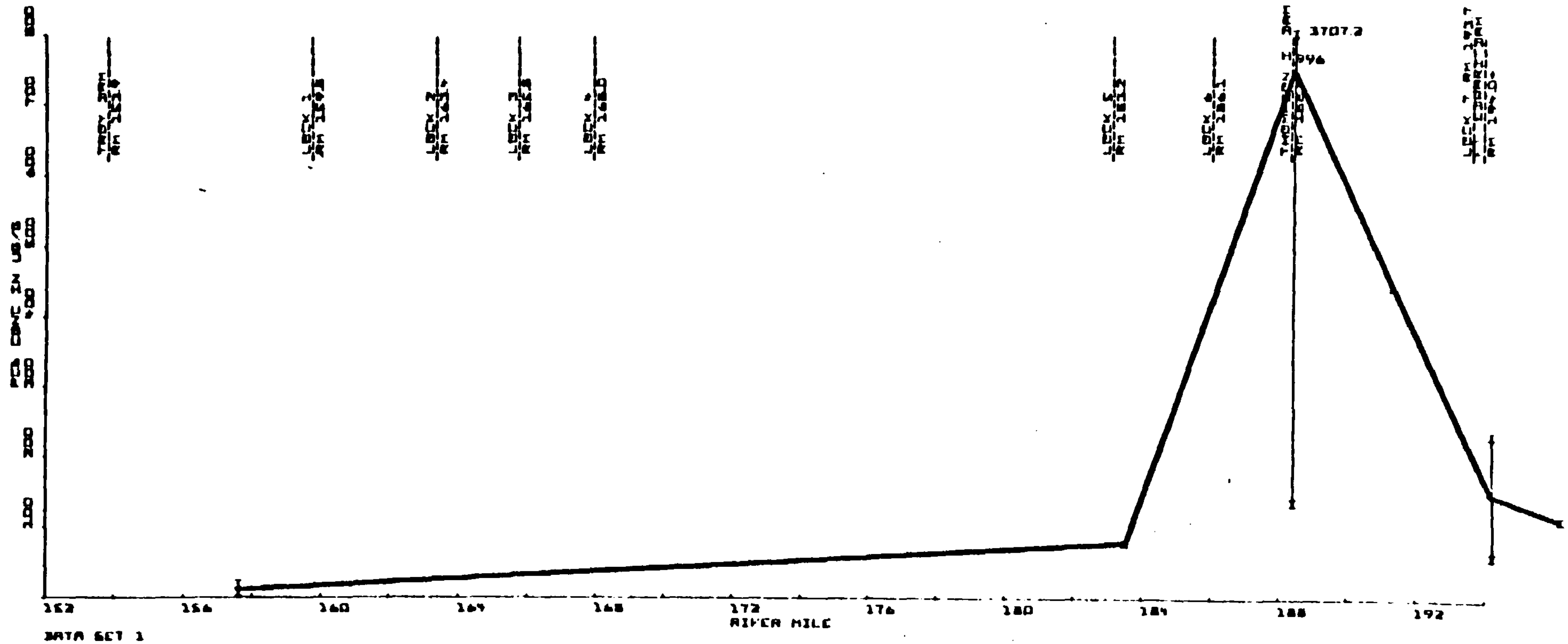


Figure II-1

PCB CONCENTRATION VS RIVER MILE
DATA SET 2 (DEC WINTER 1976)

NOTES:

1. I denotes maximum and minimum values observed at each river cross section.
2. ——— indicates the unweighted average of PCB concentrations at each cross section.
3. PCB concentrations greater than 800 ug/g are plotted at 800 ug/g, with the actual maximum noted.

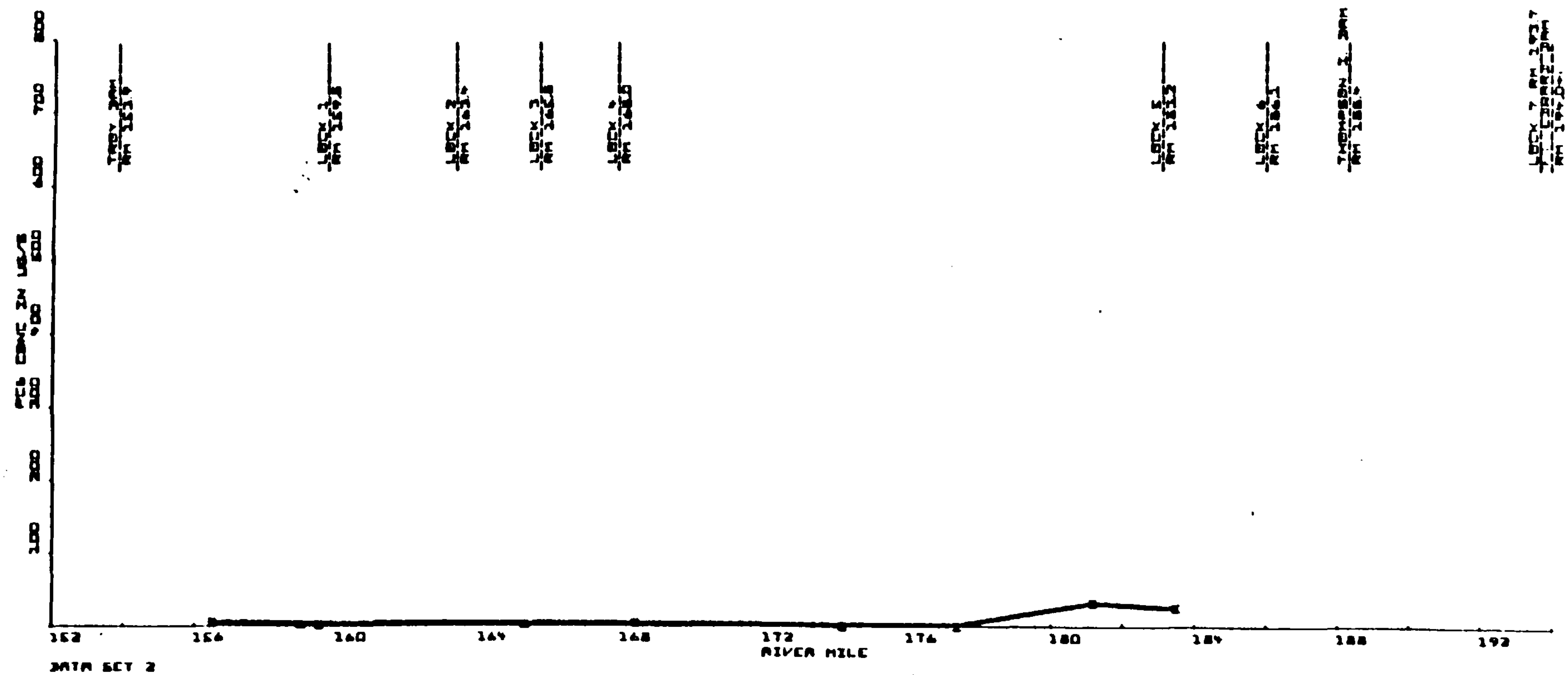


Figure II-2

Data Set 2A (LMS Winter 1976)

This data set consists of six bed material surface grab samples taken with a ponar sampler, and two core samples, collected between March 8 and March 9, 1976 by the firm of Lawler, Matusky and Skelly. Four of the surface and one of the core samples are within the study reach. PCB values range from 100 μg per g near the south end of Rogers Island (RM 193.7) to 3 μg per g at River Mile 193.2.

A plot of PCB concentration versus river mile for Data Set 2A is presented in Figure II-3.

Data Set 3 (DEC Summer 1976)

This data set consists of nine samples collected between May 5 and June 28, 1976. Seven of the samples were taken within the study area. PCB values range from 293 μg per g measured in the vicinity of the Thompson Island Dam (RM 188.5) to 2.9 μg per g measured between Thompson Island and Fort Miller (composite of 15 in. long sections taken between RM 186.1 and 188.4).

A plot of PCB concentration versus river mile for Data Set 3 is presented in Figure II-4.

Data Set 4 (DEC Fall 1976)

This data set consists of 118 surface grab (ponar) and core samples taken in September 1976. Eighty-eight of these were analyzed for PCB concentration by O'Brien & Gere Laboratory and 30 by the New York State Department of Health (DOH). PCB values ranged from 1,028 μg per g measured in the bottom segment of an 8-inch core taken at the mouth of the Moses Kill(RM 189.2), to less than 0.04 μg per g measured near the Fishermans Rest Marina Ramp (RM 177.4).

A plot of PCB concentration versus river mile for Data Set 4 is presented in Figure II-5.

Data Set 5 (Normandeau Winter 1977)

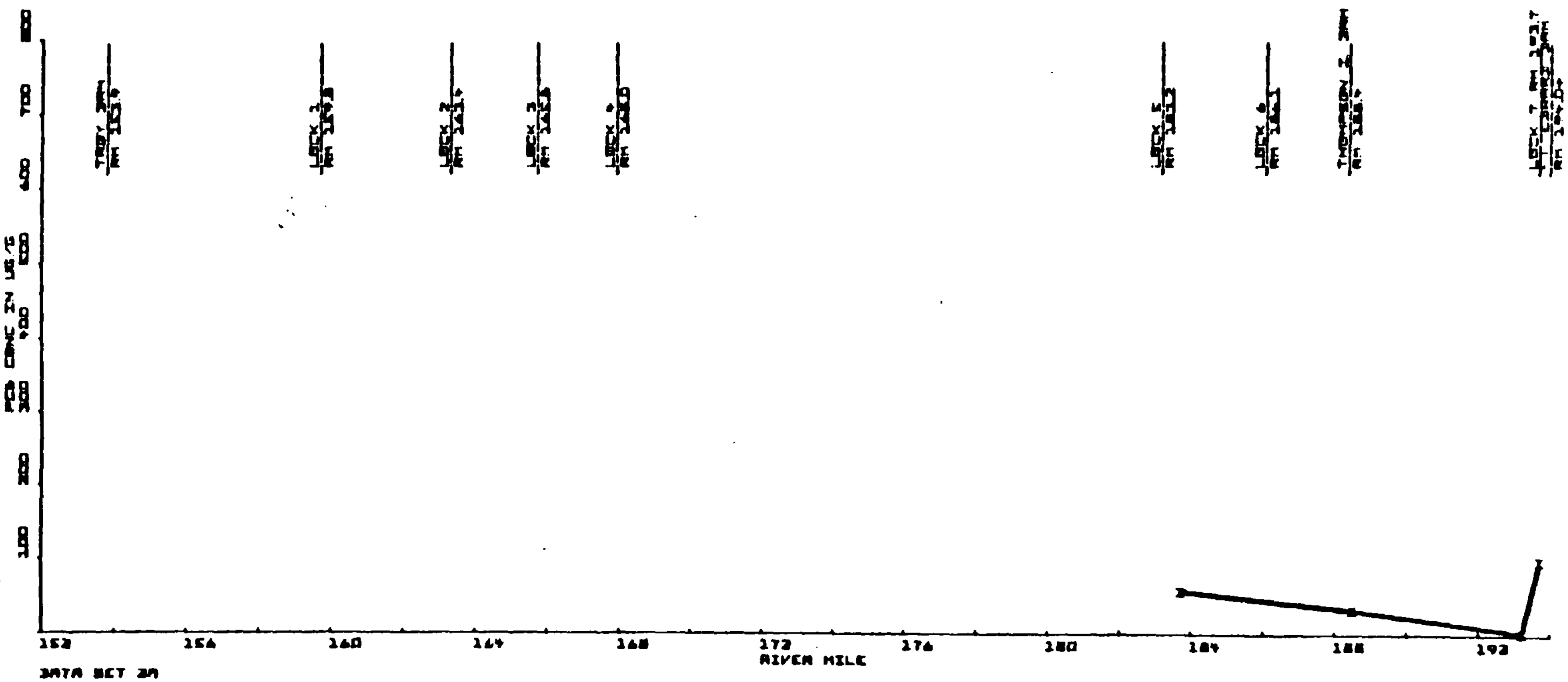
This data set consists of 397 samples from 19 cores collected between January 24 to 28 and February 9 to 13, 1977. Not all of the 397 samples have been, or are intended to be analyzed. Of the samples analyzed, PCB values ranged from 2,273 μg per g measured 4 in. deep in a core taken just north of the Thompson Island Dam (RM 188.4), to less than 0.02 μg per g measured 28 in. deep in a second core taken about 1,300 feet from the first (RM 188.5).

A plot of PCB concentration versus river mile for Data Set 5 is presented in Figure II-6.

PCB CONCENTRATION VS RIVER MILE
DATA SET 2A (LMS WINTER 1976)

NOTES:

1. I denotes maximum and minimum values observed at each river cross section.
2. ——— indicates the unweighted average of PCB concentrations at each cross section.
3. PCB concentrations greater than 800 ug/g are plotted at 800 ug/g, with the actual maximum noted.



PCB CONCENTRATION VS RIVER MILE
DATA SET 3 (DEC SUMMER 1976)

NOTES:

1. I denotes maximum and minimum values observed at each river cross section.
2. ——— indicates the unweighted average of PCB concentrations at each cross section.
3. PCB concentrations greater than 800 ug/g are plotted at 800 ug/g, with the actual maximum noted.

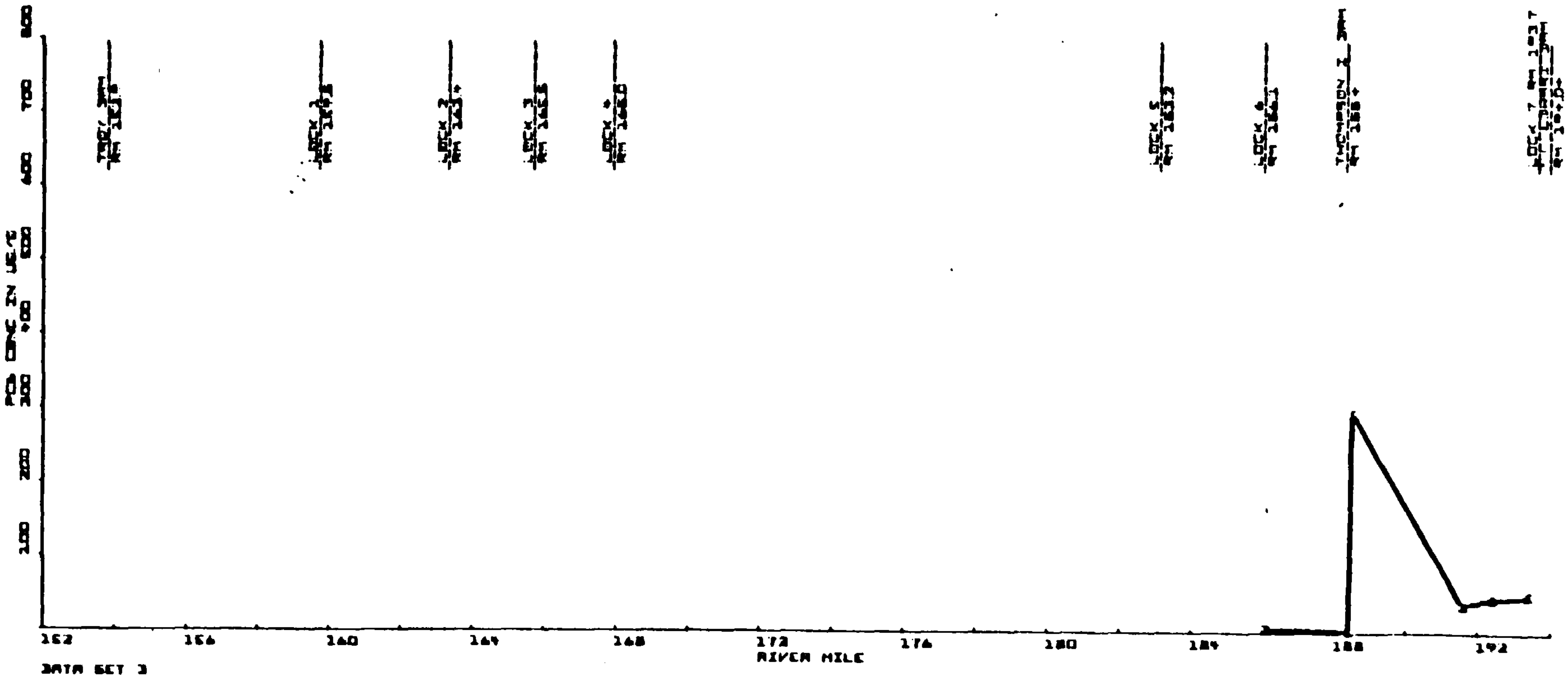


Figure II-4

PCB CONCENTRATION VS RIVER MILE
DATA SET 4 (DEC FALL 1976)

NOTES:

1. I denotes maximum and minimum values observed at each river cross section.
2. . . . indicates an envelope of PCB concentrations defined by the range of concentrations at each cross section.
3. ——— indicates the unweighted average of PCB concentrations at each cross section.
4. PCB concentrations greater than 800 ug/g are plotted at 800 ug/g, with the actual maximum noted.

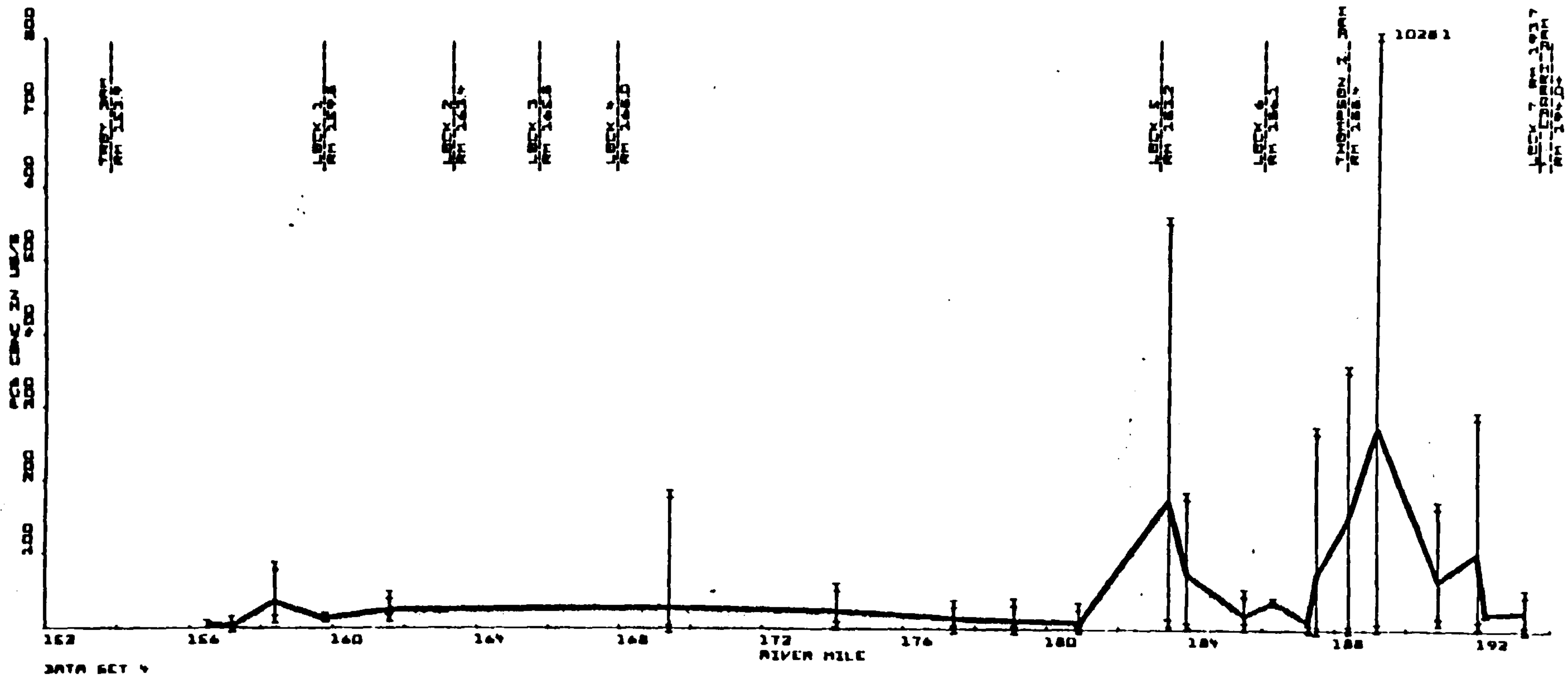


Figure II-5

PCB CONCENTRATION VS RIVER MILE
DATA SET 5 (NORMANDEAU WINTER 1977)

NOTES:

1. I denotes maximum and minimum values observed at each river cross section.
2. ..... indicates an envelope of PCB concentrations defined by the range of concentrations at each cross section.
3. ——— indicates the unweighted average of PCB concentrations at each cross section.
4. PCB concentrations greater than 800 ug/g are plotted at 800 ug/g, with the actual maximum noted.

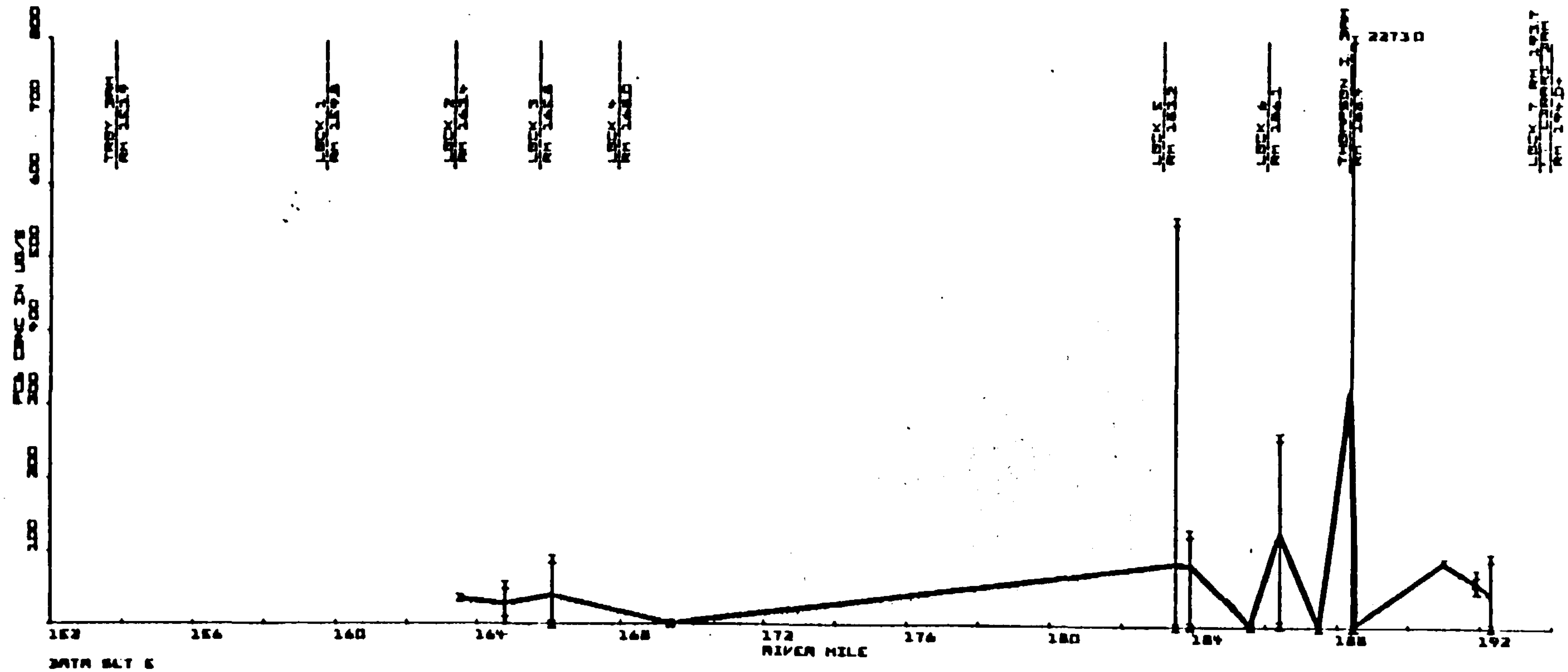


Figure II-6

Data Set 6 (Normandeau Spring 1977)

This data set consists of in excess of 600 surface grab and core samples, collected primarily in the spring of 1977, by Normandeau Associates, Inc. (NAI). NAI also performed grain size analysis on the river bed material samples, and measured river cross sections.

Sample location and PCB concentration have been plotted, at a scale of one-inch equals 200 feet, on a base map compiled from NAI/Col-East mapping. These maps are available for inspection.

The samples collected are not distributed uniformly over the study area. Table II-1 presents the distribution of all PCB samples collected in 1976 and 1977, which have been analyzed for PCB content as of December, 1977. This table shows that the density of PCB sampling ranges from 8 samples per sq mi in the pool above Federal Dam at Troy, to 421 samples per sq mi in the Thompson Island Pool. The overall average is 107 samples per sq mi, or about 1 sample every 6 acres.

A plot of PCB concentration versus river mile for all samples analyzed during 1976 and 1977 is presented in Figure II-7.

TABLE II-1

DISTRIBUTION OF PCB SAMPLES
ALL DATA, 1976 and 1977

Pool Reach	Cores	Surface Grab	Total	PCB ≥ 50 μg/g	PCB ≥ 100 μg/g	Total Pool Area (sq mi)	Samples/ Sq Mi
	Number of Samples						
1. Federal Dam - Lock 1	3	4	7	1	0	0.88	8
2. Lock 1 - Lock 2	1	7	8	1	0	0.66	12
3. Lock 2 - Lock 3	2	12	14	2	1	0.51	27
4. Lock 3 - Lock 4	6	31	37	8	5	0.51	71
5. Lock 4 - Lock 5	65	17	82	10	3	1.97	42
6. Lock 5 - Lock 6	16	106	122	45	26	0.42	290
7. Lock 6 - Thompson Island Dam	36	40	76	23	14	0.34	224
8. Thompson Island Dam - Lock 7	65	230	295	74	38	0.70	421
TOTAL	194	447	641	164	87	5.99	107

PCB CONCENTRATION VS RIVER MILE
ALL 1976 AND 1977 DATA

NOTES:

1. I denotes maximum and minimum values observed at each river cross section.
2. indicates an envelope of PCB concentrations defined by the range of concentrations at each cross section.
3. —— indicates the unweighted average of PCB concentrations at each cross section.
4. PCB concentrations greater than 800 ug/g are plotted at 800 ug/g.

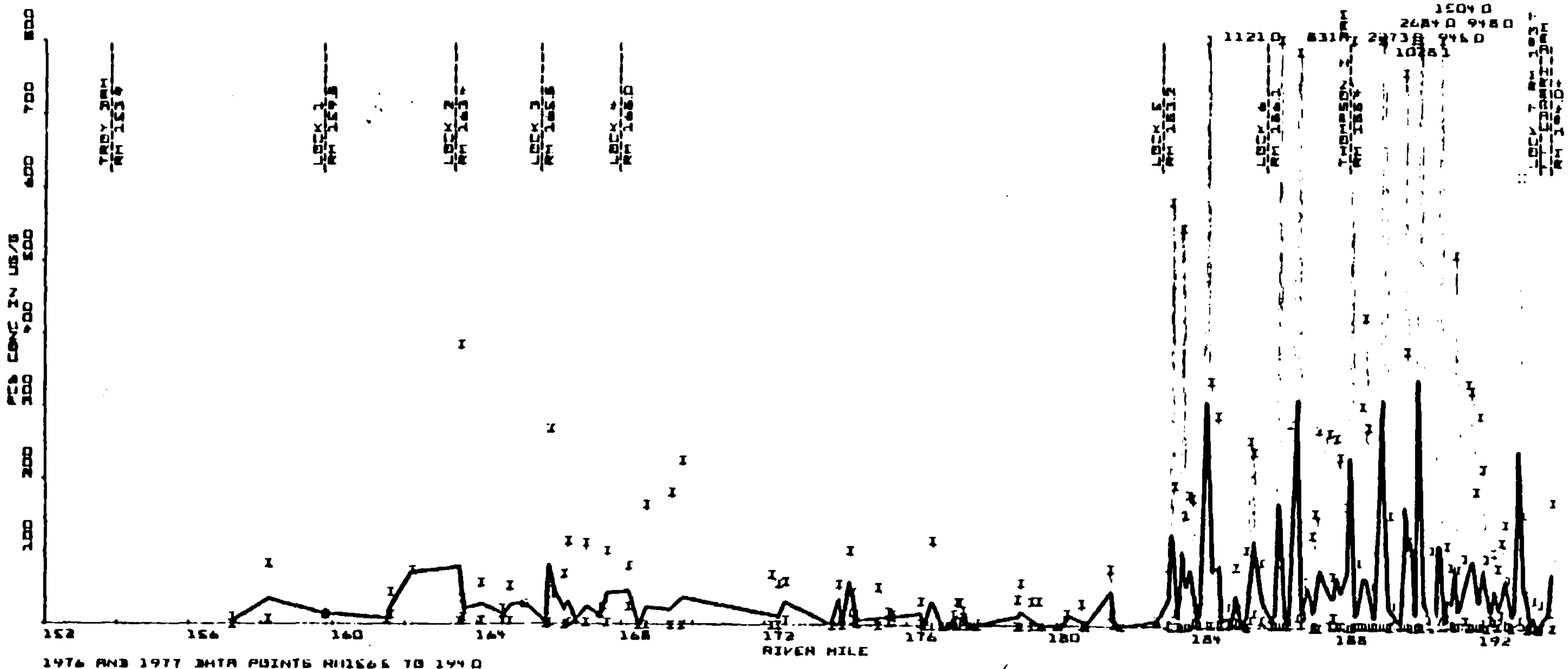


Figure II-7

Depth of Contamination

Core samples indicate that PCB concentrations vary as a function of bed material sample depth. Figures II-8, II-9 and II-10 present PCB concentration as a function of bed material sample depth for all cores selected in 1976 and 1977. These data are presented separately for each of the eight pools which comprise the Upper Hudson. Based on these plots it appears that, in the Thompson Island Pool, contamination (defined as a PCB concentration ≥50 μg per g)* is limited to the top 24 in. of the bed material. In the Lock 5 and Lock 6 pools contamination appears to be limited to the top 15 in. In the remaining pools data are insufficient to establish the depth of contamination. For the purpose of calculating PCB quantities this report will assume a depth of contamination of 15 in. in the remaining pools. It is suggested that this assumption be checked by obtaining additional core samples in the Federal Dam through Lock 4 pools.

*The contamination level of 50μg per g was established by DEC staff.

Pool Characteristics

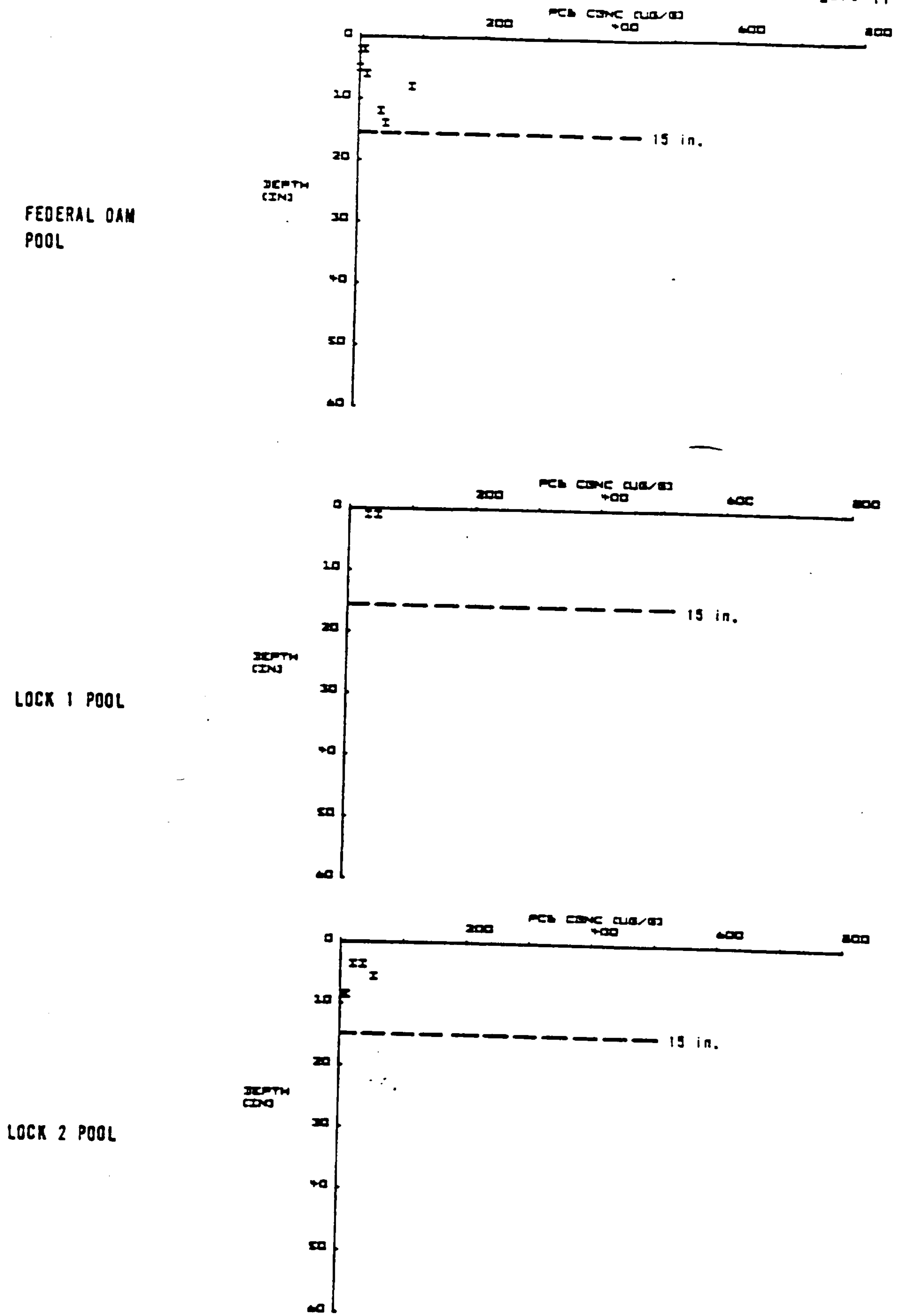
Pool characteristics were determined from base maps prepared from the NAI/Col-East mapping and are tabulated in Table II-2.

TABLE II-2

UPPER HUDSON RIVER
POOL CHARACTERISTICS

Pool	Length (Miles)	Average Width (ft)	Total Area (acres)	Rapids (acres)	Net Area (acres)
Federal Dam (RM 153.9)	5.5	845	560	0	560
Lock 1 (RM 159.4)	4.0	875	420	20	400
Lock 2 (RM 163.4)	2.6	1050	330	15	315
Lock 3 (RM 166.0)	2.2	1230	330	0	330
Lock 4 (RM 168.2)	15.2	690	1260	30	1230
Lock 5 (RM 183.4)	2.8	800	270	25	245
Lock 6 (RM 186.2)	2.3	790	220	0	220
Thompson Island (RM 188.5)	5.2	710	445	0	445
TOTAL	39.8	796	3835	90	3745

Figure II-8



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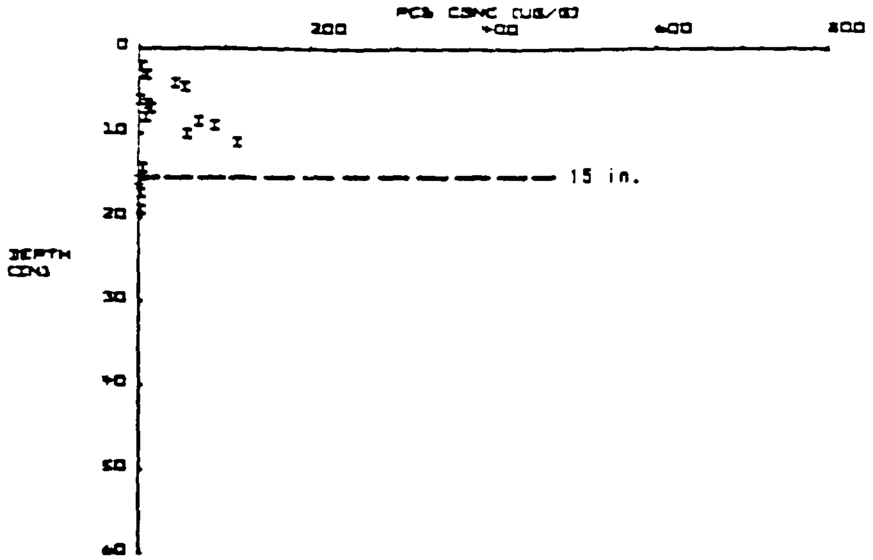
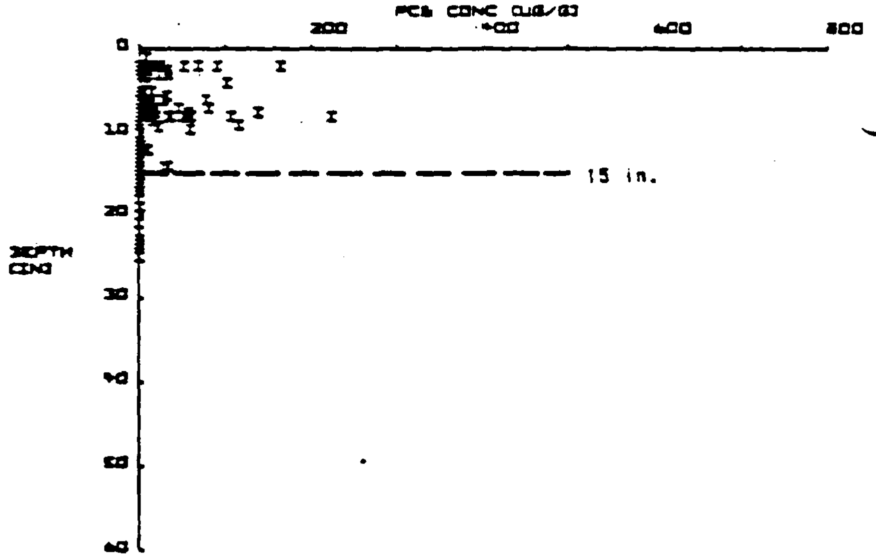
1976 AND 1977 CORE SAMPLES

PCB CONCENTRATION VERSUS DEPTH OF SAMPLE

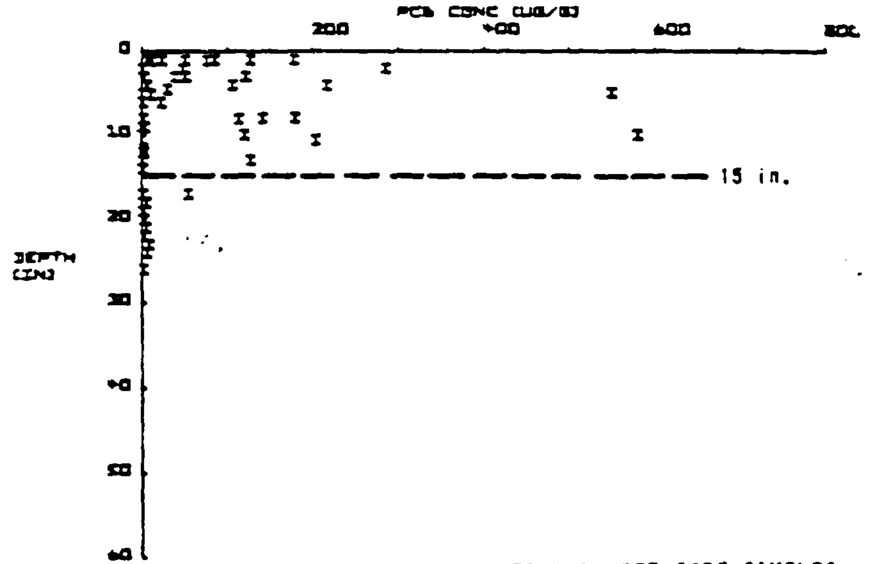
LOCK 3 POOL



LOCK 4 POOL



LOCK 5 POOL



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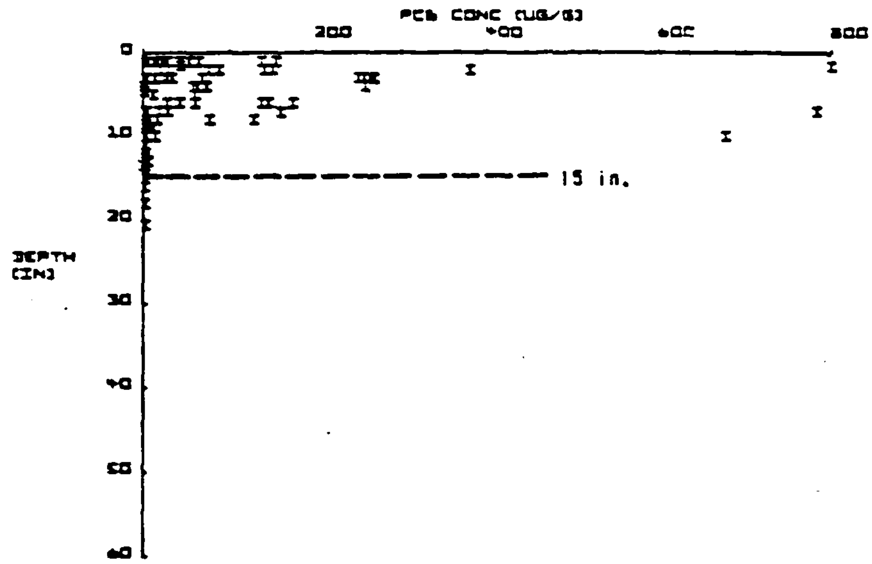
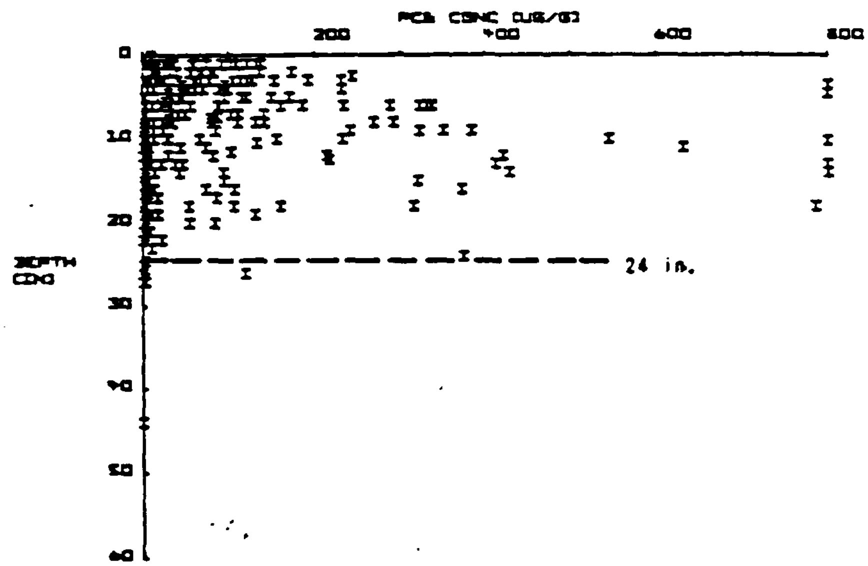
1976 AND 1977 CORE SAMPLES

PCB CONCENTRATION VERSUS DEPTH OF SAMPLE

LOCK 6 POOL



THOMPSON
ISLAND
POOL



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1976 AND 1977 CORE SAMPLES

PCB CONCENTRATION VERSUS
DEPTH OF SAMPLE

PCB Distribution With Depth

In calculating average PCB concentration it must be remembered that much more data on surface concentrations are available than for concentrations at depth. Therefore, a simple arithmetic average of all PCB values would tend to underweight the below surface data obtained from the cores.

In Figure II-11 a logarithmic plot of the weighted average PCB concentration in each core versus the weighted average PCB concentration of the top 3 in. of that core is presented. Separate lines are plotted for river segments, each approximately 2 miles in length. This plot does not include cores less than 6 in. in total length, or cores with no PCB values greater than 5 μg per g. Also, PCB values at depths greater than 24 in. are not included.

Although the data plotted in Figure II-11 exhibits considerable variation, the trend indicates that the depth weighted average of the top 3 in. of any core is a reasonable approximation of the depth weighted average of the whole core. The PCB value measured by a surface grab sample is approximately equal to the value measured by the top 3 in. of a core. It was, therefore, concluded that a surface grab sample, taken at a particular point, represents a good approximation of the depth weighted average PCB concentration that a core, taken at that point, would have exhibited.

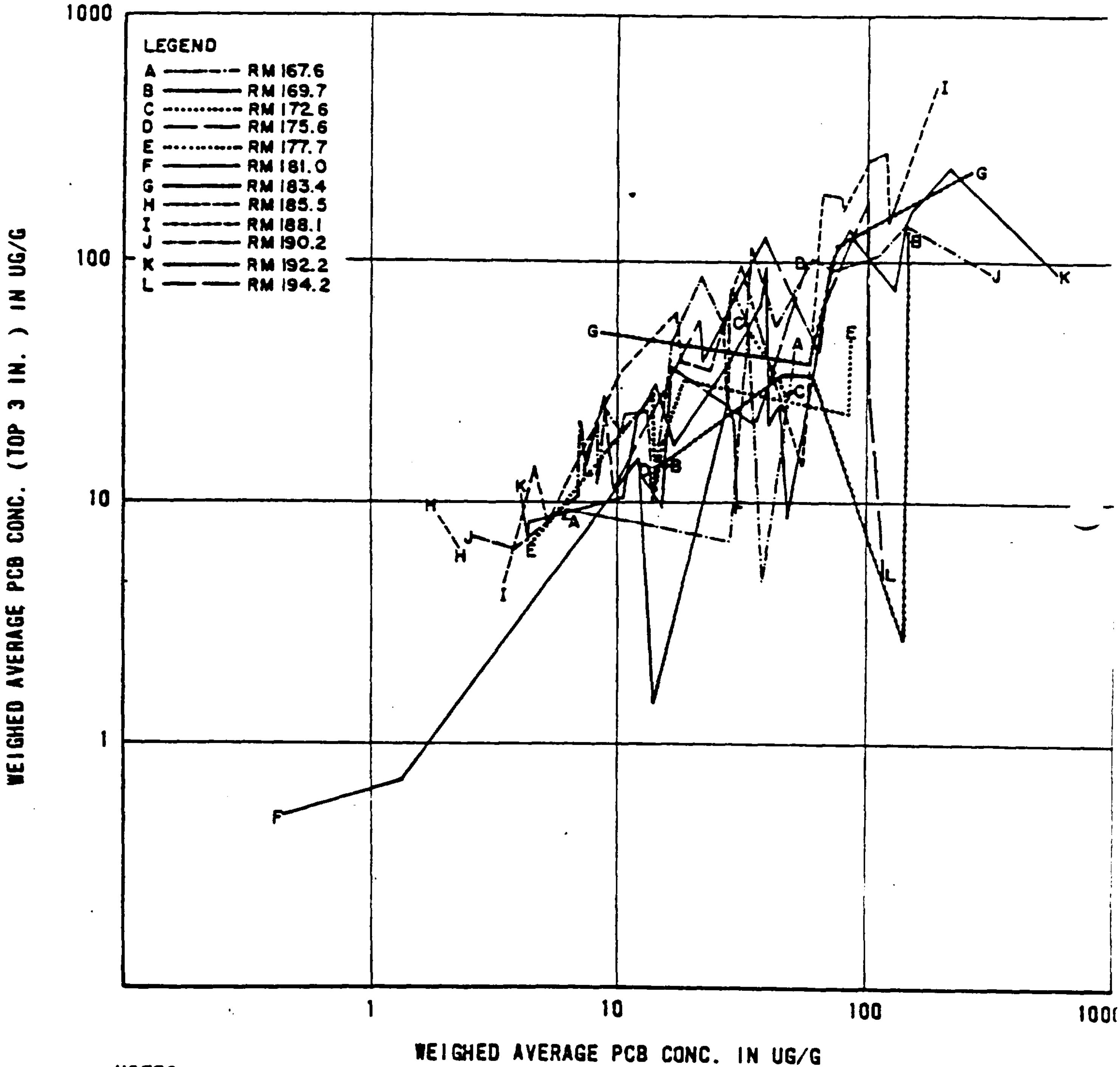
Average PCB concentrations for a given area were, therefore, determined by first calculating the depth weighted average of the core samples taken in that area, and then averaging these weighted averages with all the surface grab samples taken in the same area.

PCB Quantities

PCB quantities depend on average PCB concentration and volume of contamined material. The volume of contaminated material, in turn, depends on the area of contamination, the percentage of the river bed covered with material in that area, and the depths of contamination.

To determine average PCB concentration all PCB surface grab and core samples were plotted on base maps. As discussed above, the depth weighted average of each core was used.

In the Lock 5, Lock 6 and Thompson Island Pools sufficient data were available to permit delineation of "hot spots", defined as areas containing PCB contamination greater than 50 μg per g. In these pools, average PCB concentration, and total PCB quantity, was calculated separately for these hot spots and for the remainder of each pool. Average PCB concentration for these pools was then calculated by dividing the total PCB quantity in each pool (areas ≤50 μg/g



NOTES:

1. Cores ≤6 in. total length not included.
2. Cores with all PCB values ≤5 ug/g not included.
3. PCB values at depths ≤24 in. not included.

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plus areas ≤50 μg/g), by the total contamined volume in that pool.

In the remaining five pools it was not possible to establish "hot spots" because of lack of data. In these pools the average PCB concentration was calculated simply by averaging all the surface grab samples, in each pool, together with the depth weighted average for each core in that pool.

Average PCB concentration in the eight pools ranged from 20 μg per g in the Federal Dam Pool to 65 μg per g in the Lock 5 Pool. The overall average for the Upper Hudson was found to be 35 μg per g.

The volume of contaminated material was based on the net area for each pool, as tabulated in Table II-2, depth of contamination, and percentage of the river bed covered with sediment and debris.

Data on bed material coverage in the Upper Hudson is not extensive. The 1976 DEC Data Summary[1] estimated sediment cover at 50 percent in the Lock 3 and Lock 4 pools, and 70 percent in the remainder of the Upper Hudson. A DEC sampling program, in the summer of 1977, in the Lock 6 pool, using a ponar sampler, had a sample retreival efficiency of 74 percent. In the opinion of DEC personnel, failure to retrieve a sample indicates the bottom was rock.

Data from the NAI sampling program indicates a sample retrieval efficiency of approximately 98 percent. Possible reasons for this higher recovery rate include use of a large sampler, and a sampling methodology which included repeated attempts at retrieval, including repositioning of the sampler, if required.

Based on the data discussed above, it has been assumed that 80 percent of the river bottom is covered with debris and sediment requiring dredging.

Table II-3 tabulates and summarizes the PCB quantity calculations discussed above. This table indicates a total PCB quantity in the Upper Hudson of approximately 392,000 lbs.

It should be noted that the data on the Lock 6 Pool was not as extensive and tended to be more clustered than the data for the Lock 5 and Thompson Island Pools. For this reason, it was considerably more difficult to delineate "hot spots" in this pool, as compared with the pools above and below. The strategy adopted in this pool was to delineate the entire pool a "hot spot", except for those areas where the data clearly and consistantly showed PCB concentrations less than 50 µg per g. It is recognized that this technique may tend to overestimate PCB quantites. Nevertheless, it is believed that, given the data available at this time, it is

TABLE II-3

UPPER HUDSON RIVER PCB QUANTITIES

Reach	Net Area (10^6 Sq Ft)	Bed Material Coverage (%)	Effective Area (10^6 Sq Ft)	Depth of Contamination (in.)	Contaminated Volume (10^6 Cu Yd)	Average PCB[1] Concentration (µg/g)	PCB Quantity[2] (10^3 lbs)
Federal Dam	24.4	80	19.5	15	0.90	20	31.6
Lock 1	17.4	80	13.9	15	0.64	25	28.1
Lock 2	13.7	80	11.0	15	0.51	50	44.8
Lock 3	14.4	80	11.5	15	0.53	40	37.2
Lock 4	53.6	80	42.9	15	1.99	20	69.8
Lock 5	10.7	80	8.5	15	0.39	65	44.5
Lock 6	9.5	80	7.7	15	0.36	55	34.7
Thompson Island	19.4	80	15.5	24	1.15	50	100.9
TOTAL	163.1		130.5		6.47	35	391.6

[1] Arithmetic average Pool 1 through 5, weighted average Pools 6 through 8.
[2] Bed material density 65 lbs per cu ft.

prudent to be conservative in estimates of PCB quantities, and associated removal costs.

DEC staff have also reviewed the PCB data on the Upper Hudson, and have estimated overall PCB quantities 20% less than estimated in this report. For the Lock 6 Pool in particular, different conclusions have been reached with regard to contamination. DEC staff believes that the extent of "hot spots" in the pool are much more limited, and that the depth of contamination does not exceed 12 in. Based on these assumptions, the contaminated volume in the Lock 6 Pool would be reduced to 296,000 cu yd, and the PCB quantity reduced to 15,000 lbs. This would reduce the average PCB concentration in this pool to 29 μg per g.

It is believed that the actual quantity of PCB in the Lock 6 Pool is somewhere between the values in Table II-3, and the values calculated from the DEC assumptions. Similar differences in estimated PCB quantities exist for the remaining pools. Pending acquisition of additional data, this report will use the values of Table II-3.

Additional Data Requirements

Although large amounts of data on the Upper Hudson has already been collected as part of these investigations, there are still certain areas which could benefit from additional investigation.

1. <u>Additional PCB Data</u> - Numerous samples were collected as part of the NAI sampling program, but have not yet been analyzed for PCB concentrations. Analysis of these samples would further clarify the PCB distribution in the Upper Hudson.

2. <u>Additional PCB Samples</u> - As shown in Table II-1, PCB samples are very sparse in the first five pools in the Upper Hudson, and especially in the Federal Dam and Lock 1 Pools. Although this report has calculated PCB quantities based on such data as is available, it is quite possible that significant PCB deposits may have been missed, with sampling frequency of 8 samples per sq mi, as in the Federal Dam Pool.

3. <u>Bed Material Probing Data</u> - Very little data exists on the actual depth to bedrock along the river bed of the Upper Hudson. As discussed in detail in Chapter 6, this information is quite important to planning a dredging program, and could be gathered, at relatively little expense, by probing the river bed.

In addition to the data discussed above, it should be noted that a specific dredging program will require a more detailed PCB mapping effort, which would presumably be included as part of the design phase of the dredging project. The type and extent of the data required would depend on the dredging program selected.

REFERENCES

CHAPTER II

1. NYSDEC, "Hudson River PCB Monitoring, Data Summary-Past, Present and Future", (1976).

2. Malcolm Pirnie, Inc., "Revised Interim Report, Data Base", (1977).

CHAPTER III

DREDGING TECHNOLOGY

Introduction

A dredge may be defined as a machine which removes materials from the bottom of waterways by means of scooping or suction devices. The removal of contaminated sediments is not a traditional dredging activity although no other system known can excavate this bottom material as economically. New technologies are being developed and applied to dredging which are expected to increase removal efficiency and minimize the loss of fine grained materials at the dredgehead. Some of these new systems are described herein.

There are three primary dredging methods in use today: hydraulic, mechanical, and pneumatic. This chapter investigates the types of dredges available in each category, their advantages and disadvantages in terms of cost, time, loss of material, depth requirements, and sediment types handled.

The transport of dredged material is an important aspect of dredging and is generally performed by pipelines, barges, or trucks. Transport types are often determined by the dredge system chosen: for example, material dredged hydraulically is generally conveyed by pipeline to the disposal site. This report investigates the types of transport available and their advantages and disadvantages in terms of travel time to the disposal site, cost, secondary pollution and return flow treatment requirements.

Some of these dredges (hopper, sidecasting etc.) are clearly not feasible for the Hudson River problem. Brief descriptions have, however, been given for background purposes.

Material for this chapter was obtained from texts on dredging, World Dredging Conference (WODCON) publications, manufacturers' catalogues, discussions with dredge manufacturers and consultants and reports on dredging studies.

Hydraulic Dredges

Dredges which operate hydraulically use water as a medium to convey the dredged material. The material to be excavated is mixed with water and pumped through the system by a centrifugal pump as a slurry (generally 10 to 20 percent solids content). The material is transported to a spoil lagoon where the sediments are allowed to settle out. Owing to the large flows associated with this system, the disposal sites are relatively large to include areas for decanting the fined grained sediments as well as treatment of return water before discharge to the waterway. In addition, certain types of sediment exhibit a phenomena known as "fluffing" wherein the dredged material occupies a different volume in the disposal area than in the river or lake bottom. The fluff factor (cut to fill ratio) can range from 3 to 1 for benonitic clays and organic silts to 0.85 to 1 for sands.

The following types of hydraulic dredges are discussed in this report:

- Cutterhead suction
- Plain suction
- Dustpan
- Hopper
- Sidecasting
- Clean Up

Advantages and disadvantages are summarized following a description of each type.

<u>Cutterhead Suction</u> - This type of dredge excavates subaqueous material by means of a rotating cutter at the end of a suction pipe. The cutter suspends material into a slurry which is then pumped hydraulically and discharged through a floating pipeline to shore. The dredge advances by swinging from side to side using spuds at the rear as pivots. Lateral movements are controlled by swing cables attached to anchors. The depth of cut is manually controlled by the operator who may raise or lower the ladder cutterhead. This type of dredge is illustrated in Figure III-1.

Dredge size is determined by the diameter of the discharge line. Sizes generally range from 6 to 42 in. with dredges in the 12 to 16 in. range suitable for dredging in the Upper Hudson.

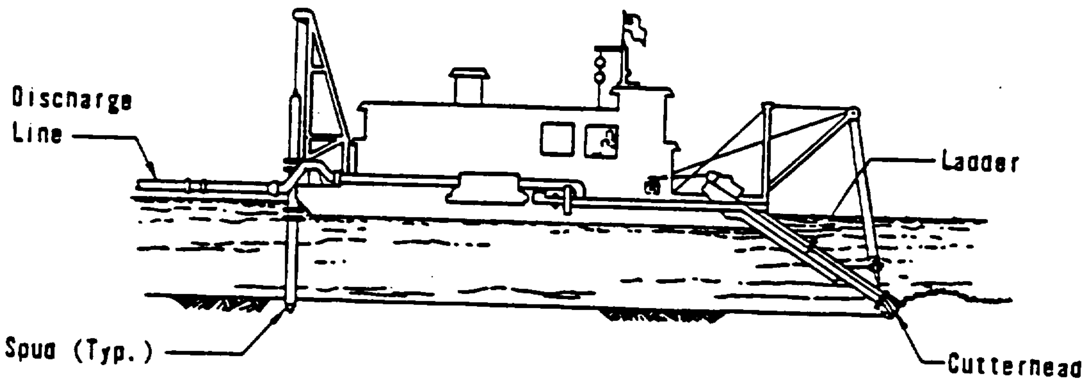
In general, 12 to 16 in. dredges are approximately 50 ft in length, 20 feet in width and require 3 to 4 ft draft. Production varies considerably with dredged material characteristics and piping lengths; ranges from 150-850 cu yd per hour are typical. Twelve to 16 in. dredges will efficiently excavate medium clays, silt, sand, gravel and soft rock. Material loss at the cutterhead can be controlled to some extent by the operator by varying the rate of ladder swing and cutter rotation speed. Twelve to 16 in. dredges generally have a maximum dredging depth of 25 to 30 ft. Purchase price varies from $250,000 to $1,000,000, depending on the quantity of auxillary equipment included.

<u>Advantages</u>

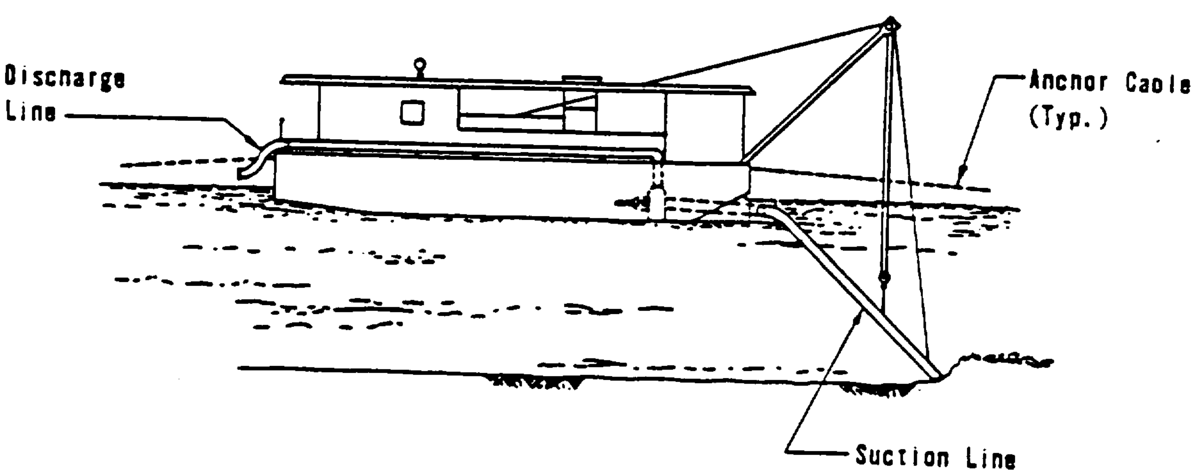
- Large volumes of material are moved economically because of a virtually continuous operating cycle. High production for size of plant.

- A wide range of materials, from light silts to heavy rock blasted to small sizes, can be excavated with a properly designed cutterhead.

- The use of booster pumps in the pipeline allows material transport over relatively long distances from the waterway to the disposal site.



CUTTERHEAD SUCTION DREDGE



PLAIN SUCTION DREDGE

- There is no rehandling of the sediment from the cutterhead to the spoil lagoon.

Disadvantages

- The floating pipeline and swing wires can be a obstruction to navigation.
- There is agitation and disturbance of the bottom sediment. Materials loss is a function of operational procedures.

Plain Suction - These are similar to ordinary cutterhead dredges except for the absence of the cutter. Occasionally, these dredges are equipped with a special suction head which uses water jets to loosen the material. Only loose and free-flowing sediments can be dredged using such equipment. See Fig. III-1.

Advantages

- Large volumes of the proper material can be moved economically.
- With booster pumps, the slurry can be transported over long distances to the disposal site.
- There is no materials handling beyond the dredge head.

Disadvantages

- The floating pipeline and swing wires can be an obstruction to navigation.
- Because of the nature of the material to be dredged, this system has a limited use in a waterway where a wide variety of sediment types exist.
- In the dredging of non-optimal materials, very low production rates are observed.

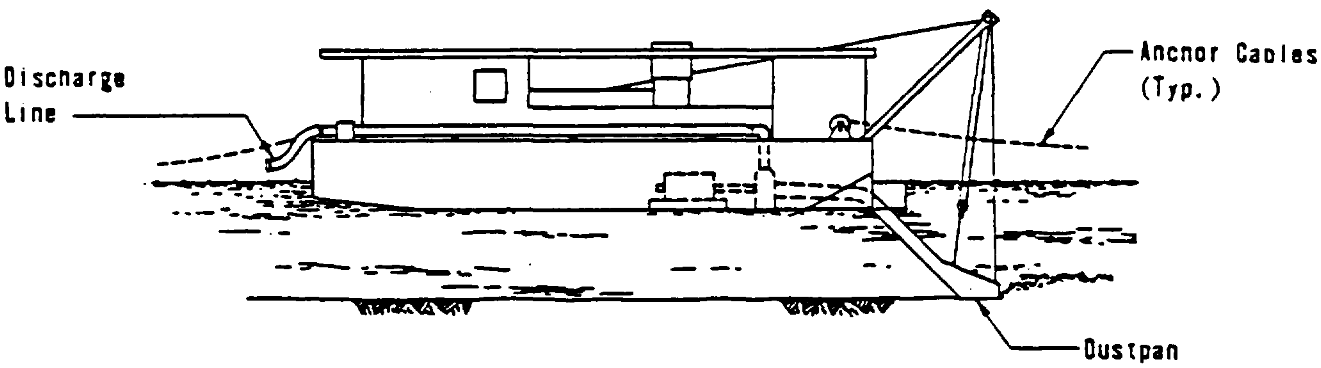
Dustpan - This plant is an adaptation of the plain suction dredge. The suction head resembles a large dustpan and has been primarily used to remove sandbars in the Mississippi River. The dredge head is generally 32 ft wide with a rectangular opening 31 ft wide and 16 in. high. Equally spaced vertical members are fitted accross the inlet to prevent oversized material from entering the suction. These members terminate in water jet nozzles to break up the sands and silts and form a slurry which can be pumped through the system. The dredge is slowly pulled towards two prepositioned anchors or spuds, generally placed upstream of the dredge. The slurry is usually discharged from a short pipeline in the water adjacent to the dredge. See Fig. III-2.

Advantages

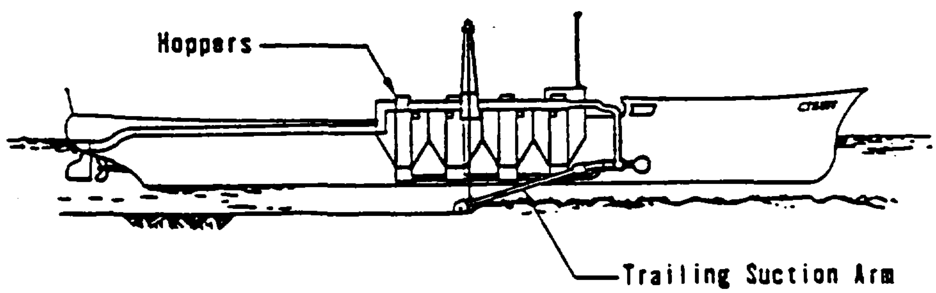
- The material is forced into the suction resulting in a slurry with a high solids content. High production for the size of plant.

Disadvantages

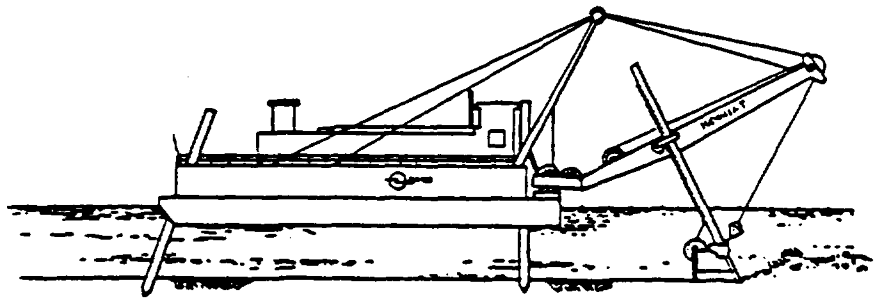
- The nature of the disposal operation resuspends a large amount of material. In the case of contaminated material, this is environmentally unattractive.
- As for the plain suction dredge, this system is best suited for a certain type of material and is of limited use in dredging an area with a wide variety of sediments and trash.



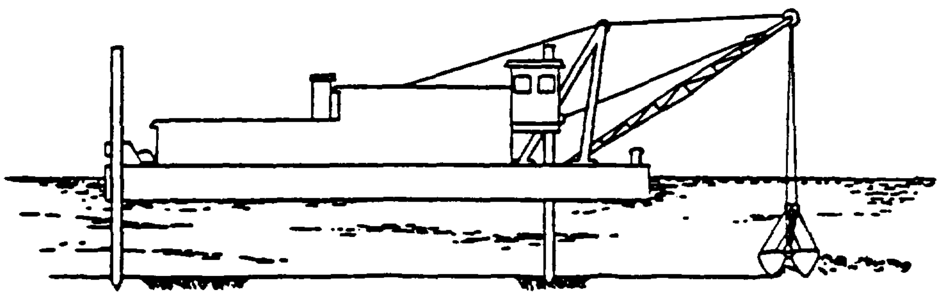
DUSTPAN DREDGE



HOPPER DREDGE



DIPPER DREDGE



CLAMSHELL DREDGE

- Normal mode of dustpan operation (i.e. sidecasting) is not suitable. This operation could be modified at additional cost.

Hopper - The hopper dredge is an ocean-going ship and functions like a plain suction dredge. The dredging operation is accomplished by two trailing drag arms extending from both sides of the ship to the waterway bottom. The material is removed from the bottom by suction and pumped into hopper bins aboard the ship. In general, dredging is continued beyond the point where the bins overflow to increase the amount of solids contained in the hoppers. When the hoppers are filled the dredge proceeds to deep water dumping grounds where the bins are opened and the material discharged. As an alternative, the bins may be pumped out and the slurry discharged in spoil lagoons as in conventional hydraulic dredging practice. The dredge hopper sizes generally vary from 300 to 12,000 cu yd and a minimum draft of 15 ft is usually required for operation. Shallow draft hopper dredges are presently under development by the Corps of Engineers to operate in less than 15 ft of water. Production for a 3,000 cu yd hopper capacity ship is roughly 500,000 cu yd per month. See Fig. III-2.

Advantages

- The dredge is self-propelled and removes material while underway with no moorings or cables.

- There is minimum interference with navigation because of the dredge's high mobility. Can operate in rough waters.

- Suitable for all but the hardest materials. Production depends on the travel time to the dumping grounds and the mode of hopper discharge.

<u>Disadvantages</u>

- The overflow of the hopper bins resuspends fines, as does the bottom dumping of the dredged material. In dealing with contaminated materials, this method of operation is undesirable.

- A hopper dredge is an ocean going ship, and, as such, cannot be used in the Upper Hudson.

<u>Sidecasting</u> - This type of dredge is a relatively new development, which removes material by a draghead sliding over the bottom and discharges the material over the side of the vessel in the water through a 70 to 250 ft boom. The system is best suited for littoral or estuarine areas. The range of materials handled by the sidecasting dredge is similar to that excavated by the hopper dredges. The first sidecasting dredge was a converted tanker but smaller plants are manufactured today which can operate in 5 feet of water.

<u>Advantages</u>

- The dredges are self-propelled and therefore highly mobile. They are best suited for operating in shallow ocean inlets.

- There is minimum interference with navigation and the dredge can operate in rough waters.

Disadvantages

- The method of disposal of the dredged material is self-defeating when dredging contaminated materials.

Clean-Up - The Clean-Up dredge is a hydraulic suction dredge modified by the replacement of a conventional cutter-head with a new suction design. The new suction head consists of an underwater pump and a shielded auger-like mixing device. There is also a movable plate which deflects currents generated by the dredge suction and a device for collecting gases released during the dredging process. Sonar devices and an underwater television camera permit close monitoring of the dredging operation.

This equipment has been developed by the Toa Harbor Works of Japan and is used exclusively for the removal of highly contaminated material.

Advantages

- Turbidity generation and resuspension of fines is held to a minimum by special suction devices and by giving the operator an accurate picture, through sensors, of the most suitable operating conditions.
- The use of sonar devices and television cameras allow accurate cutterhead positioning.
- The advantages listed under the cutterhead suction dredge also apply here.

Disadvantages

- This dredge is not available in the United States at this time.

- It has a relatively low production rate and is therefore expensive. Trash and heavier materials would probably impede the successful operation of this machine.

<u>Mechanical Dredges</u>

Dredges which operate mechanically remove the bottom material with excavation devices but do not transport it to the disposal site. A fleet of barges and tugs are used for this purpose. All mechanical dredge types resemble dry land excavation equipment; in fact, in many cases surface equipment is floated on a barge and used for dredging.

This report disucsses four types of mechanical dredges:

- Dipper
- Clamshell
- Bucket
- Dragline
- "Closed bucket" clamshell

<u>Dipper</u> - This dredge is essentially a barge mounted power shovel. The material is broken off by the force of the cutting edge of the shovel while the dredge remains stationary. The shovel is lifted through the water and the sediments are deposited in a barge or on shore. It is best used in the excavation of hard, compacted materials, and rock and demolition debris. See Fig. III-3.

<u>Advantages</u>

- As the dipper stick forces the bucket into the material a strong "crowding" action is noted. Hard, compacted materials and demolition debris are best excavated by this system.

- The dredged material approaches in-place density in sands and silts and approaches dry density in coarser materials.

- This system may be readily assembled.

Disadvantages

- Low production for size of plant and investment.

- The dredging method generates a large amount of turbidity during excavation and as the bucket is raised through the water.

Clamshell - This dredge consists basically of a derrick mounted on a barge with a "clam shell" bucket for excavating. The material is removed by forcing the opposing bucket edges into the sediment. The bucket is lifted out of the water and deposits the spoil on a barge or on shore. The dredge itself remains stationary. This system works best in soft and cohesive materials. A wide variety of bucket and barge sizes are available.

Figure III-3 shows a typical clamshell dredge.

Advantages

- The dredge plant is readily available and easily assembled.

- Can work effectively in confined areas near docks and breakwaters.

- The dredged material approaches the in-place density in mud and silt.

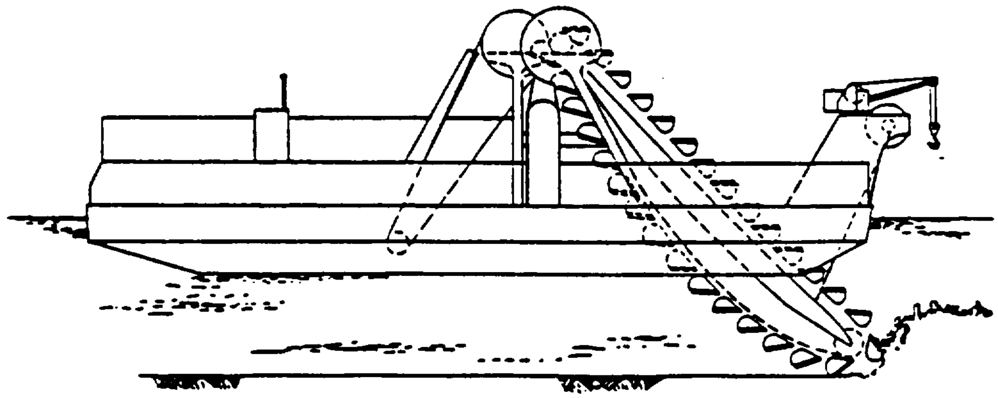
Disadvantages

- In dredging very soft deposits, material washes out of the bucket. In dredging very hard materials, the bucket cannot penetrate the surface of the sediments and little material is excavated.
- Debris may not permit the full closure of the bucket jaws with attending material loss.
- There are technical problems in dredging sludges and sands which form a thin layer. The method of dredging results in the considerable agitation of sludges and other loose materials.
- Relatively low production.

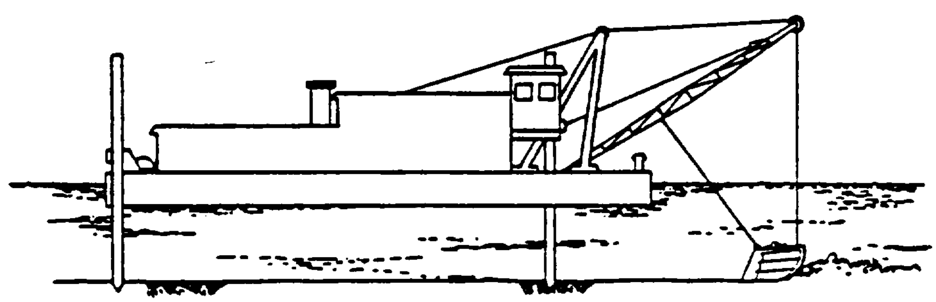
Bucket - The bucket dredge is composed of an endless chain of buckets pulled around a dredging ladder. The sediment is removed by forcing the single cutting edge of each bucket into the material as the dredge is slowly moved between anchors. As the filled bucket rotates over the top tumbler, the load is dumped on an inclined chute to a hopper or barge.

This dredge is extensively used in Europe for all dredging purposes. In the United States, this system is used in the commerical production of sand and gravel and in the recovery of various ores and precious metals. It is suitable for dredging all but the very hardest materials.

Figure III-4 shows a typical bucket dredge.



BUCKET DREDGE



DRAGLINE DREDGE

MALCOLM PIRNIE, INC.

Advantages

- In dredging at large production rates (1,500 cu yd per hr), the bucket dredge uses less than half the power required by a cutterhead suction dredge of equivalent size.
- The dredge operates more efficiently than other mechanical dredges because the excavation process is continuous. High production for its size.
- The material dredged approaches the in-place density in muds and silts. Approaches dry density in coarser materials.

Disadvantages

- Rehandling of dredged material required.
- The nature of the operation results in sediment disturbance and resuspension of fines through the excavation process and as the filled buckets move through the water column.
- This dredge is apparently not available in the United States as a dredge plant. It is used only as part of mining plant in sand and gravel operations.

Dragline - This dredge plant is generally composed of a crane having a bucket suspended from a swinging boom which is mounted on a barge or truck. The dredge operates by scraping the material from the bottom by pulling the bucket towards the stationary crane. The spoil is lifted and deposited on a barge or on the bank. This system is readily available in a wide variety of sizes and is suitable for all but the hardest material. See Fig. III-4.

Advantages

- This system is frequently used to remove sediments found in shallow water.
- The dredge is quickly assembled.
- Works well in moderate swells and waves.
- The material dredged approaches the in-place density in muds and sitls.

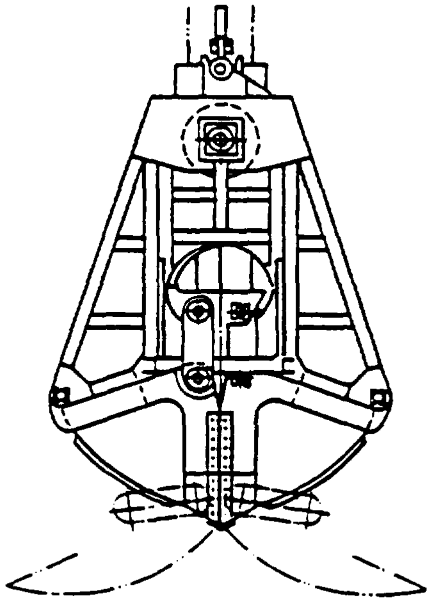
Disadvantages

- Rehandling of dredged material required.
- Considerable turbidity may be created during the operation depending on the nature of the material to be dredged.
- This dredge has a low production and the work cannot be as precisely controlled as required to remove contaminated sediments.

"Closed Bucket" Clamshell

This is a recent modification of the clamshell dredge developed in Japan. Operation and design are as for a standard clamshell except that the bucket itself is specially designed to be watertight thus minimizing loss of material during the dredging process. This is achieved by the use of an upper cover closing the bucket top, and by the use of special seals along the bucket edges.

Figure III-5 shows two typical closed buckets, as manufactured by the Mitsubishi Seiko Co., Ltd., of Japan, and of two types of seal mechanism used for such a bucket.



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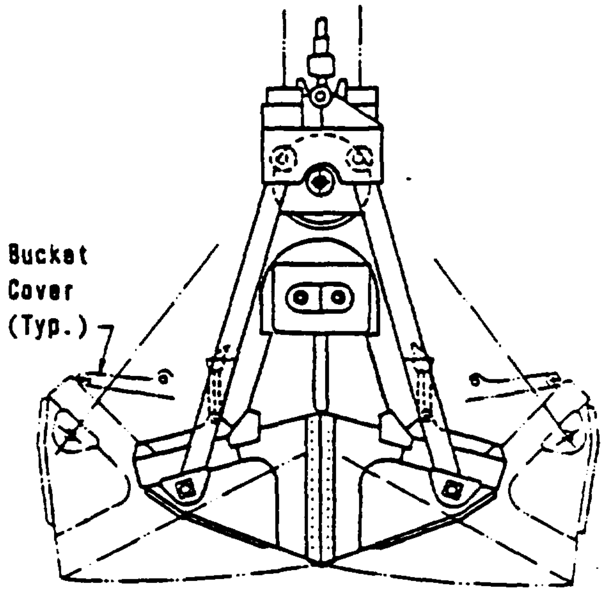
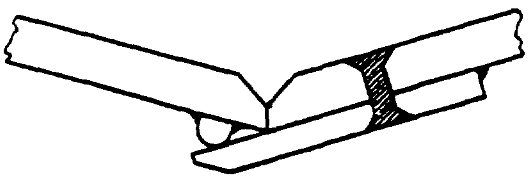
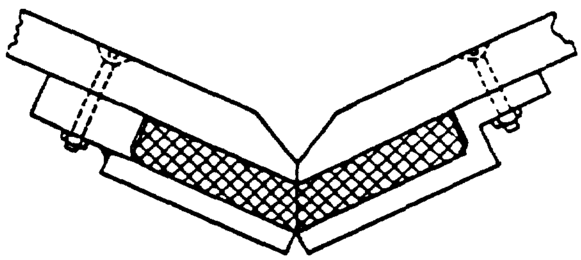


LATERAL DREDGING TYPE

MITSUBISHI CLOSED GRAB BUCKET



TWO-PLANE CONTACT METHOD



HARD RUBBER METHOD

LIP SEALING METHODS

SOURCE: MITSUBISHI SEIKO CO., LTD.

Advantages

- Dredging in mud the bucket can excavate with a minimum of sediment loss and turbidity.

Disadvantages

- The bucket's sealing mechanism is unlikely to work well dredging in coarse and debris-laden material as on the Upper Hudson.
- The bucket does not appear to be available in the USA at this time.

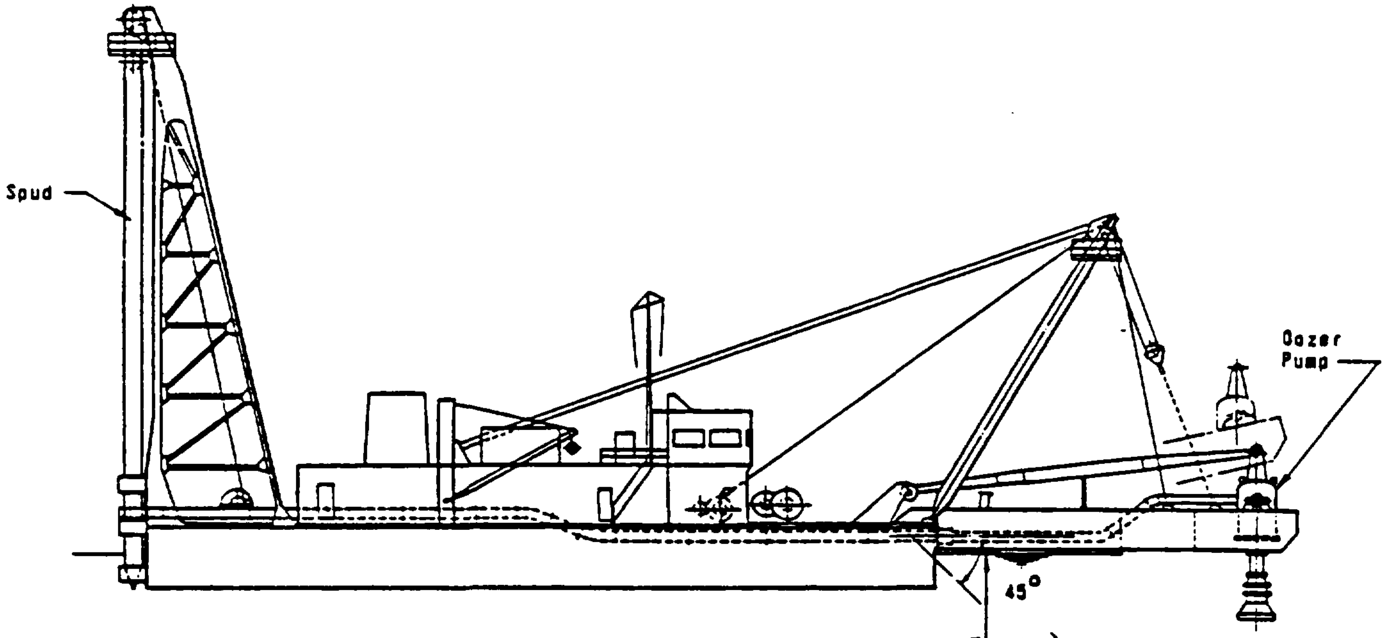
Pneumatic Dredges

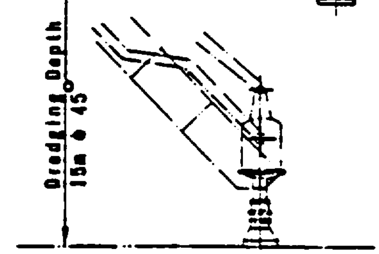
These systems are a recent innovation in the dredging field. Hydrostatic head is used to force sediment into the dredge head from which it is ejected by pneumatic pressure. There are few moving parts in contact with the dredged material and, as a result, little wear and cavitation is experienced. Sludges, muds, and other loose and free-flowing materials can be removed at higher densities than generally experienced with hydraulic dredges. This material may be dumped in hopper barges or pumped to a suitable disposal site.

Two companies are known to manufacture pneumatic dredge heads: Pneuma International S.A. (Pneuma), and the Toyo Construction, Ltd. (Oozer). The method of operation of these two pneumatic devices is very similar and is described below.

The Oozer and Pneuma devices are operated by compressed air. Water pressure (hydrostatic head) at the dredge intake is used to load material into cylinders which are then evacuated by compressed air. To obtain a smooth flow of dredged material, two or three cylinders are used, their cycles set at different points so that material is always flowing through the delivery pipeline. The deeper the system is lowered, the greater the head and the production rate. The system includes a barge upon which the compressors, air distributing units and winches are mounted, and a submersible pneumatic device (dredge head) which is lowered for dredging purposes.

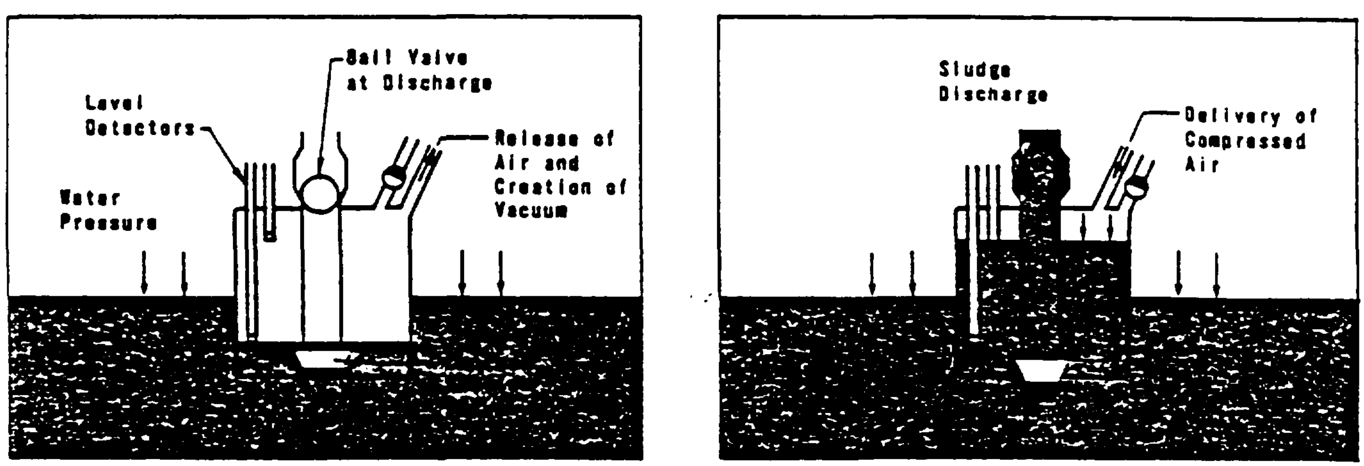
Oozer - The Oozer pump dredge consists of four components: an air compressor, a vacuum pump, a pump control valve, and a pump tank. Suction pressure is supplied by the positive water pressure on the sediment layer and the negative pressure generated inside the tank. The sediment in the tank is discharged by forcing in compressed air. The suction and discharge cycles are controlled by two level detectors. To improve the suction process, a vacuum pump capable of generating a vacuum of 300 to 500 mm Hg is used. This allows the production rate to be less dependent upon depth of submergence. The dredge is operated in the same manner as a hydraulic dredge by swinging the craft from deadmen and using two spuds for control and propulsion.





THE TAIAN MARU

Length	37m (121.4 ft)
Width	12m (39.4 ft)
Depth	3m (9.8 ft)
Draft	2.2m (7.2 ft)



SUCTION

DISCHARGE

OOZER PUMP OPERATION

MALCOLM PIRNIE, INC.

SOURCE: TOYO CONSTRUCTION CO.

The Oozer was developed by the Toyo Construction Co., Ltd., of Japan, Figure III-6 illustrates the operation of the Oozer pump, and shows the Taian Maru, an oozer-equipped dredge owned and operated by Toyo Construction.

Advantages

- This system generates very little turbidity and does not resuspend fines.
- Hazardous substances are less likely to be dissolved into the dilution water as compared to a centrifugal pump.
- The system can be easily modified to dredge near breakwaters and docks. An underwater TV camera and a device which measures sediment thickness allow precise monitoring of the dredge cut.

Disadvantages

- This system is not currently available in the United States.
- A wide variety of materials are to be dredged in the Hudson, most of which are not suitable for removal by this system.
- Limited pumping distance for horsepower of dredge.

Pneuma - This system is similar to the Oozer dredge with the following exception: after the sludge has been discharged and the compressed air vented, the tank pressure is allowed to return to atmospheric. No vacuum pump is used to create negative pressure as is done in the Oozer system. Therefore, the depth of submergence has a greater effect on production rates in the Pneuma system.

Advantages

- See those listed under the Oozer system. The monitoring capabilities are not as extensive, however.

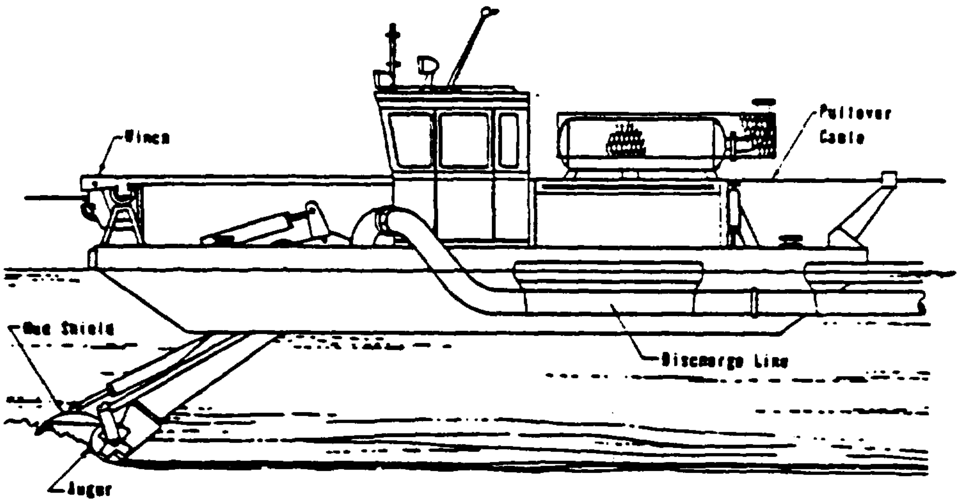
Disadvantages

- The dredge pump is not effective at depths less than 12 ft because of low hydrostatic pressure.
- There are only two units available in the United States today.
- There is a possibility of trash becoming lodged in the cylinders. This would clog the control valves and impede the pumping cycle.
- Only soft and free-flowing materials can be effectively dredged.

Other Systems

The dredging systems discussed in this section are not easily categorized. Mud Cat and Delta are modified hydraulic dredges exhibiting unique dredge head characteristics. These enable the dredges to work in restricted areas such as lagoons and canals. The IHC Amphidredge is a very versatile machine which can dredge mechanically or hydraulically and is capable of self locomotion on land by hydraulic "legs". The final dredging system investigated, the Terra Marine Scoop, is a land based dragline capable of reaching 2,000 ft. Each is described below.

Mud Cat - This dredge is a small, truck transportable hydraulic dredge which is designed to clean out sludge pits,



MUD CAT DREDGE

SOURCE: MUD CAT DIVISION
NATIONAL CAR RENTAL

MALCOLM PIRNIE, INC

industrial waste areas, and silting in small canals and reservoirs. The dredge head is comprised of an 8 ft wide, auger type, horizontal cutterhead surrounded by a mud shield. The auger pulls the material towards the pump suction intake, through a centrifugal pump and out an 8 in. pipeline to a disposal site.

Figure III-7 illustrates a Mudcat Dredge.

Advantages

- Operates near breakwaters, docks, and other confined areas such as sedimentation lagoons.
- Portable, easily obtainable, shallow draft machine (27 in.).
- Turbidity generation can be controlled by the utilization of the mud shield and by the auger-like cutter head arrangement which crowds the material into the suction pipe.

Disadvantages

- Cannot easily dredge coarse or hard materials.
- The low production rate (50-120 cu yd per hour) is best suited for small jobs.
- Limited dredging depth (10.5 ft).
- Not expected to perform satisfactorily because of river debris.
- After each pass, the barge must be pulled over 8 ft by pullover cables and the pipeline length adjusted until the project's completion. This operation interferes with navigation.

IHC Amphidredges - These machines are small dredging units designed for the maintenance of ditches, irrigation and drainage canals, city canals, fresh water reservoirs, and construction projects such as pipeline trench excavation in marshy and shallow areas. Three kinds of dredging techniques are available from IHC Holland: Clamshell grab dredging, cutter suction dredging, and backhoe dredging.

Clamshell grab dredging units consist of a self-powered grab dredge crane installed on a floating pontoon system. The crane may embark and disembark under its own power from the pontoon. The minimum water depth required is 0.5 m (19 in.) and the bucket is available in 350 and 500 l capacities (0.46 and 0.65 cu yd). The floating pontoon is pulled forward by a winching/anchor system.

Cutter suction dredging units have a milling system developed for the maintenance dredging of silt and organic sediments. A scoop is used to funnel the deposits into the direction of the suction opening. A pump is used to transport the spoil through a discharge pipeline to a disposal site. The craft is propelled forward by inching the craft along a guide wire. These dredges may be outfitted with three or four legs, allowing the machine to "turtle walk" from the transport vehicle into the water and around small bridges and other obstacles. Silts and loose materials are best dredged by this system; the production rate is roughly 150 cu yd per hour and the maximum dredging depth ranges from 11.5 to 17.5 ft.

The backhoe dredging system is composed of a main pontoon, 3 or 4 movable legs, and a hydraulic excavator with a backhoe, clam shell bucket, or mowing bucket. These units are amphibious and can move about on land or in the water. Terrestrial propulsion is accomplished by a turtle-like crawling motion. The legs also serve to steady the vehicle during dredging operations. The maximum dredging depth is 14.5 ft, the backhoe capacity is 400 l (0.5 cu yd). The dredge system is capable of excavating all but hard and compacted materials.

A typical Amphidredge is shown in Figure 111-8.

<u>Advantages</u>

- These dredges designed to operated in marshy and very shallow areas.
- Most models are equipped with legs and can get out of the water to avoid obstacles. All dredges are very mobile.
- These units exhibit a high dredging capacity in relation to size.

<u>Disadvantages</u>

- Availability may be a problem, since this dredge is manufactured in Europe, and none are in operation in the USA at this time.
- The production rate is small for the size projects which are being investigated in this report.

- These dredges will not work efficiently under conditons where the sediment contains a substantial amount of debris or heavy vegetative growth.

- The mechanical dredging units disturb the bottom, resuspending fines and generating turbidity.

<u>Terra Marine Scoop</u> - This system consists of a 3.2 cu yd scoop which is ferried on steel cables from a truck mounted winch to a deadman anchorage. As the bucket is pulled along, it is filled by scraping along the bottom. A built-in baffle plate prevents overfilling. When the bucket arrives at the dumping site the return line is pulled, rotating the scoop 90 degrees. This action empties the bucket and the scoop is pulled back to the dredging point. Built-in vents allow water and aquatic life to escape from the bucket. The truck which carries the scoop and winching mechanisms is equipped with flotation tires allowing operation in wet and marshy terrain. The system is highly mobile and can be set up or dismantled in a very short time.

<u>Advantages</u>

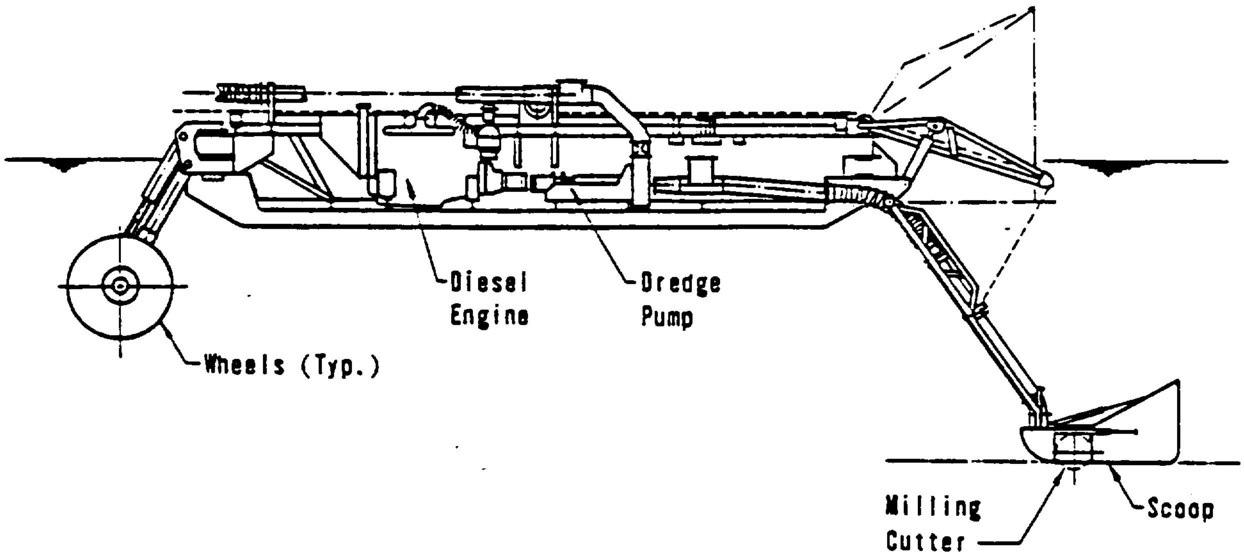
- Portable and highly mobile.

- Able to dredge in a wide variety of conditions: from swamps to 100 ft depths.

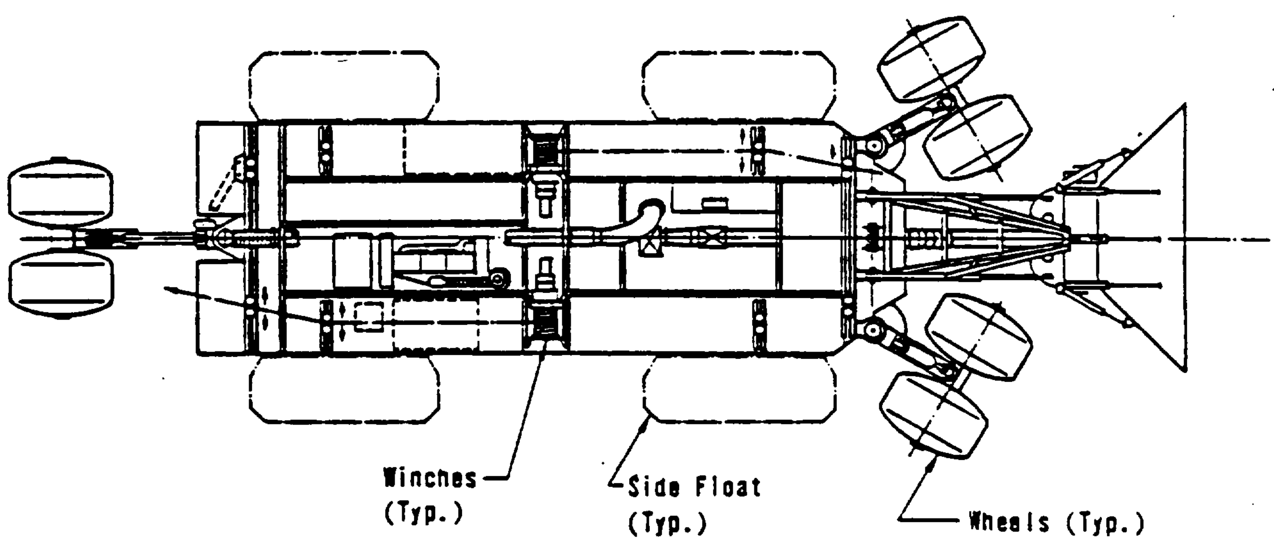
- The scoop can dredge up to 2,000 ft from shore.

<u>Disadvantages</u>

- Substantial resuspension of fines.



IHC AMPHIDREDGE
TYPE S170



SOURCE: IHC HOLLAND

- Dredge control imprecise.
- Slow and tedious operation.

Delta - The Delta dredge is a new dredging system developed for the removal of fines and silts from shallow or confined areas. The dredging operation is similar to that of a conventional cutterhead hydraulic dredge with the exception that the Delta uses small anchors rather than stern spuds to maneuver. This is possible because of the low crowding power required by the special cutterhead. The Delta cutterhead design consists of two counter rotating cutters providing a 7.5 ft wide swath to a water depth of 16 ft. A 12 in. submersible dredge pump transports the slurry to a pipeline and, ultimately, to a disposal site.

Advantages

- Portable, shallow draft machine (32 in.).
- Cleans out silted lakes, industrial settling tanks, sewage lagoons, boat harbors, and other shallow or confined areas.

Disadvantages

- Not generally available, only limited number have been manufactured.
- Does not efficiently dredge coarse sand and gravel.
- Method of operation results in a resuspension of fines and increases the turbidity of the water column.

Types of Transport Systems

Pipeline - Material dredged as a slurry is generally transported by pipeline to a disposal site. The pipeline may link the dredging and disposal operation or may be used to transfer material from an unloading site, through a barge pumpout mechanism, to the disposal site. In some hydraulic dredging techniques, the pipeline is very short and is used to return the dredged material to adjacent waters (eg: sidecasting dredge). Large quantities of material may be moved through this system.

In general, abrasion resistant steel pipe is used in the construction of a pipeline. The slurry is pumped at a velocity in the range of 14 to 20 ft per second; this is to assure that the suspended material does not settle out in the pipe. Higher velocities are undesirable because of the large head losses generated.

Advantages

- Pipe is readily available.
- For short and medium distances, the pipeline system of transportation is the most cost-effective.

Disadvantages

- For long distances over rough terrain many booster pump stations are required to move the slurry to the disposal site.

- The pipeline requires a right-of-way.
- The hydraulic system generates large quantites of wastewater which must be treated. This significantly increases the cost of a project.

<u>Barge Transport</u> - Barge transport of dredged material is generally associated with mechanical dredging systems. The dredge excavates the sediment and places it on an adjacent barge, which, when filled, is towed by a tug to an unloading site. At the unloading site the material is removed and transferred to the disposal site. The transfer from the barge to the disposal site may be performed either mechanically by clamshell buckets or hydraulically by a pumpout system.

In the latter case, the pump suction is lowered into the barge, water is added, a slurry formed, and the material pumped to the disposal site. The costs and operations from the unloading site to the disposal site are similar to the costs and operations of a pipeline system. The treatment costs are comparable to those experienced in the hydraulic dredging systems.

<u>Advantages</u>

- Barge transportation is less expensive than pipeline in conveying material from one point to another over long distances.

Disadvantages

- This system involves much equipment: tugs, tenders, unloading facilities, and transportation facilities from the unloading area to the final disposal site.
- The dredged material is rehandled several times. With each rehandling, material may be lost or spilled.

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CHAPTER III

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CHAPTER IV

DISPOSAL SITES

Introduction

Perhaps the most difficult task in any contamination abatement program is the final disposition of the source contaminant. Although methods for complete destruction of PCB in contaminated material, such as incineration, are technologically possible, economics and overwhelming logistical problems preclude their immediate use for the disposal of the Upper Hudson River bed materials. Land disposal, although not a permanent solution to the contamination problem, can, in almost all cases, avoid major impacts upon the environment, assuming placement into a carefully selected site, designed to incorporate workable longterm preventive measures.

This chapter discusses disposal site selection and contains six sections:

- Screening Criteria
- Screening Methodology
- Potential Sites
- Site Selection
- Field Studies
- Disposal Site Design

The first step in disposal site selection is the establishment of management guidelines. These guidelines are used to define selection criteria by which lands within the study area may be screened.

Management guidelines for the land disposal of PCB contaminated bed materials were adopted that would:

- Assure compliance with the New York State regulations for a secure land burial facility (6 NYCRR 360, May 17, 1977) and the USEPA rules for PCB disposal (40 CFR 761, proposed);
- Avoid environmental and aesthetic conflicts;
- Allow for site preparation at a minimum cost; and
- Avoid significant incompatibility with existing land uses.

The currently proposed lower limit PCB concentration necessitating disposal in a secure disposal area is 500 µg per g. Although many areas containing bed materials exceed this limit, an overall average in the upper Hudson does not. It is expected that in the near future, levels lower than the 500 µg per g may be set by the EPA and DEC. It was therefore determined that all PCB contaminated bed materials in the study area, even those with low level and moderate concentrations, should be disposed of into secure facilities.

The screening criteria, defined by the management guidelines, incorporate: existing or pending regulations, the availability of nonavailability of a specific resource, and site preparation requirements to achieve acceptable environmental conditions in an economical manner. For example, a regulation may require a site to be underlain by highly impermeable material with a minimum depth to bedrock of 10 ft. The available options include finding a site which meets the requirements naturally or modification of a site to meet the requirements.

Screening Criteria

The screening criteria establish conditions for classifying sites as unacceptable, acceptable and ideal. Unacceptable conditions are those that, because of environmental, social, and/or economic constraints would preclude the use of the site. Acceptable conditions are those that by virtue of a natural condition or an easily modified one, will provide for a workable and reliable site. Ideal conditions are those that represent the least potential for conflict, while still allowing for siting in a general area. Unacceptable and ideal conditions are presented in Table IV-1.

Perhaps the most important criteria from a site preparation and environmental control standpoint is the presence of relatively impermeable natural deposits. New York State requires that:

TABLE IV-1

SITE SCREENING CRITERIA

Parameter	Unacceptable	Ideal
Soil	Permeability greater than 1×10^{-5} cm/sec, less than 3 ft thick in situ. ($<1.4 \times 10^{-4}$ cm/sec overlayed) Class I or II agricultural soils	$\leq 1 \times 10^{-7}$ cm/sec, % soil passing # 200 sieve >30, in situ thickness >10 ft, liquid limit >30, plasticity index >15.
Slope	deep gullies, slope over 15%	<10%
Surface Water	Closer than 300 ft to any pond or lake used for recreational or livestock purposes, or any surface water body officially classified under state law. In special flood hazard areas or recognized wetlands.	>1000 ft from any surface water body. > 200 ft from intermittent streams.
Bedrock	Closer than 30 ft to highly fractured rock or carbonates, closer than 10 ft to all other rock.	>50 ft deep.
Groundwater	Closer than 10 ft to groundwater, wells tapping shallow aquifers, closer than 1000 ft to any water supply well. Flow towards site.	>50 ft, deep bedrock wells or no wells within 2000 ft radius.
Committed Land	Closer than 1000 ft to parks, cemeteries, residential areas, historic sites, etc.	>1500 ft away
Biologically Sensitive Areas	Endangered plant or animal habitats, unique or regionally significant environments.	no woodlands, no locally significant features.

- an impermeable barier consisting of synthetic liner or natural material of approved composition and thickness and having a hydraulic conductivity of 0.0000001 centimeters per second or less shall be placed or constructed between any deposited hazardous wastes and surrounding soil and shall be subject to approval of the Department of Environmental Conservation.

- An impermeable cap shall be placed or constructed over the top of cells within two months of their completion in such a way as to prevent water from entering the cell. The impermeable cap shall consist of a synthetic or natural material of acceptable composition and thickness and having a hydraulic conductivity of 0.0000001 centimeters per second or less and shall be subject to approval of the Department.

- The soil beneath the facility shall have a hydraulic conductivity of 0.00001 centimeters per second or less and shall be subject to approval of the Department.

Proposed Federal regulations require that the soil have a high silt and clay content with the following parameters:

- In-place soil thickness, 4 ft or compacted soil liner thickness 3 ft.

- Permeability (cm/sec), $\leq 1x10^{-7}$

- Percent soil passing No. 200 Sieve, ≥30

- Liquid limit, ≥30

- Plasticity Index, ≥15

Should any of the above not be present, an artificial liner of at least 30 mils in thickness is required.

It is anticipated that the local glacial lake clay deposits will comply with the above specification. Preliminary data has shown that the Covington, Hudson, Kingsbury, Madalin, Rhinebeck and Vergennes soil series should meet State and Federal criteria either naturally or with minor site preparation. It is therefore not expected that the installation of an artificial liner will be required.

Screening Methodology

Overlay maps illustrating individual limiting factors were developed for each of the site screening criteria, utilizing the unacceptable conditions as the exclusionary factor to be plotted. These maps were assembled from the basic information listed in the bibliography. The data were transferred to a common scale (1:24000) and drafted on clear acetate sheets. Although some degree of field precision was assumed, a moderate amount of error is likely particularly in the transfer of data from small scale maps.

The single factor overlays were superposed over a common base map so that blank zones or "windows" showing acceptable areas could be identified. This method assumes that all areas within study boundaries are at first acceptable. There is no preconception of where a disposal site should be or what land is available or suitable for such a use, except that examination was limited to a zone 2 miles on each side of the river. By using the overlay system, areas can be quickly idientifed that provide the broadest range of acceptable characteristics, and are in agreement with management guidelines. Unacceptable areas are eliminated simultaneously. Acceptable areas can then be ranked using secondary criteria such as: accessibility, size, elevation and obstacles (presence of powerlines, etc.). This method also allows further studies to be scheduled for certain remaining areas which exhibit some degree of compatibility and may be adjusted by site preparation.

This technique does not eliminate the need for on site investigations, but does limit the number of sites requiring field studies. Of the approximately 100,000 acres in the study area approximately 3,200 acres, composed of 40 parcels, were found to be acceptable as a result of the screening process.

Potential Sites

It can be seen in Plates IV-3 and IV-4 that the majority of the potential sites are on East side of the Hudson and lie between River Mile 182 and River Mile 194. Although the study concentrated on identifying potential sites within two miles of the river, an examination of outside areas concluded very few additional sites would be found by extending the study limits since conditions producing many adequate sites close to the river change drastically as one travels away from the river. The study also was limited to potential sites larger than 20 acres in size. Table IV-2 summarizes the number and size of disposal sites in the various pool reaches.

TABLE IV-2

POTENTIAL DISPOSAL SITES

Pool Reach	Pool Length Miles	Number of Potential Sites	Average	Site Area, Maximum	Acres Minimum	Total
Federal Dam	5.5	none	-	-	-	-
Lock No. 1	4.0	3	46	57	35	137
Lock No. 2	2.6	none	-	-	-	-
Lock No. 3	2.2	4	51	68	33	203
Lock No. 4	15.2	7	70	126	26	488
Lock No. 5	2.8	5	105	168	34	526
Lock No. 6	2.3	7	71	215	27	496
Thompson Island Dam	5.2	14	97	230	23	1,364
	39.8	40				3,214

Site Selection

Before a site or sites can be selected, numerous questions must be answered. Of prime concern are the amounts and location of material to be dredged, and the methods for dredging and disposal.

Dredging the entire Upper Hudson bottom bank to bank from River Mile 153.9 to 193.7 would produce approximately 14.5 million cu yd of debris and sediment. Hydraulic dredging will require, assuming a fill depth of 10 ft, approximately 900 acres of land. Mechanical dredging with a fill depth of 15 ft will require approximately 600 acres. Both estimates do not consider increase due to dike and buffer requirements, or possible fluffing of the dredged material. Of the 3200 acres identified in the screening study, probably no more than 2300 acres would be found suitable after preliminary environmental compatibility field investigations. This number would probably decrease after detailed field studies which should include borings and hydrogeologic investigations. However, it is expected that sufficient acreage is available should the whole river be dredged. This availability is a function of meeting the management guidelines for disposal sites. It does not consider the social, institutional and economic constraints to be encountered which may affect the PCB dredging project.

Informal discussions with personnel of both the EPA and DEC indicated that those charged with maintaining and monitoring the disposal sites will not favor the use of multiple sites. A number of potential sites over 100 acres exist in the Town of Fort Edward each with the capacity to handle in excess of 1 million cu yds. Individual sites in excess of 100 acres are unavailable south of Schylerville and several smaller parcels might be needed to attain sufficient acreage for large scale disposal operations.

Field Studies

Once a recommended program is initiated field surveys of potential sites are required. The sites will be screened in detail for environmental compatibility. This screening includes such factors as potential impact on surface and ground water, terrestrial and aquatic habitats, adjacent land-use, and socio-economic factor. Human interest categories such as noise, visual and traffic impact potential will also be evaluated. Prime candidate sites will undergo complete subsurface and hydrogeological investigations.

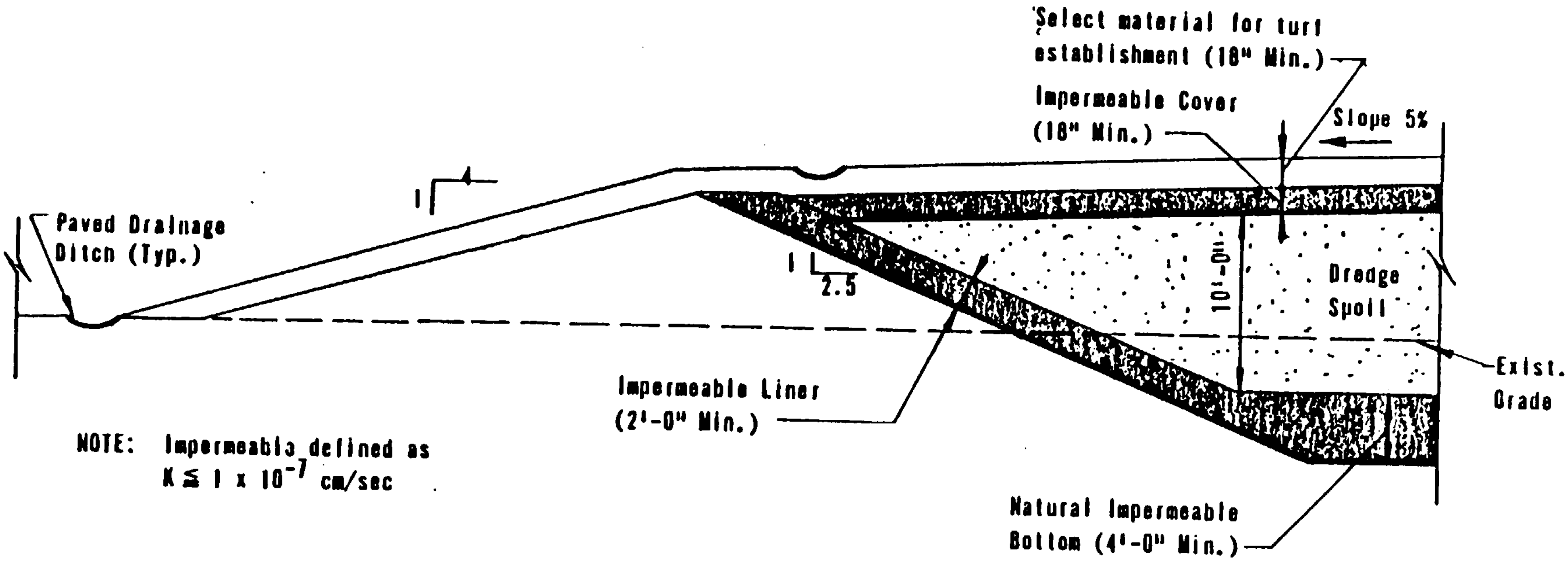
Disposal Site Design

Disposal site design will vary with dredge type. Hydraulic dredging or pumpout systems require large volume storage basins to separate the dredged material from the river water used to transport it. Clamshell excavation systems, on the other hand, require only small toe dikes at the disposal site since the dredge spoil is delivered as a stable material at low water content.

Figure IV-1 shows a sketch of a typical disposal site for hydraulic dredging systems. Features of such a site would include:

- A natural impermeable layer ($K \leq 10^{-7}$ cm/sec) at least 4 ft thick over the bottom of the site.

TYPICAL DISPOSAL SITE CONSTRUCTION
HYDRAULIC DREDGING

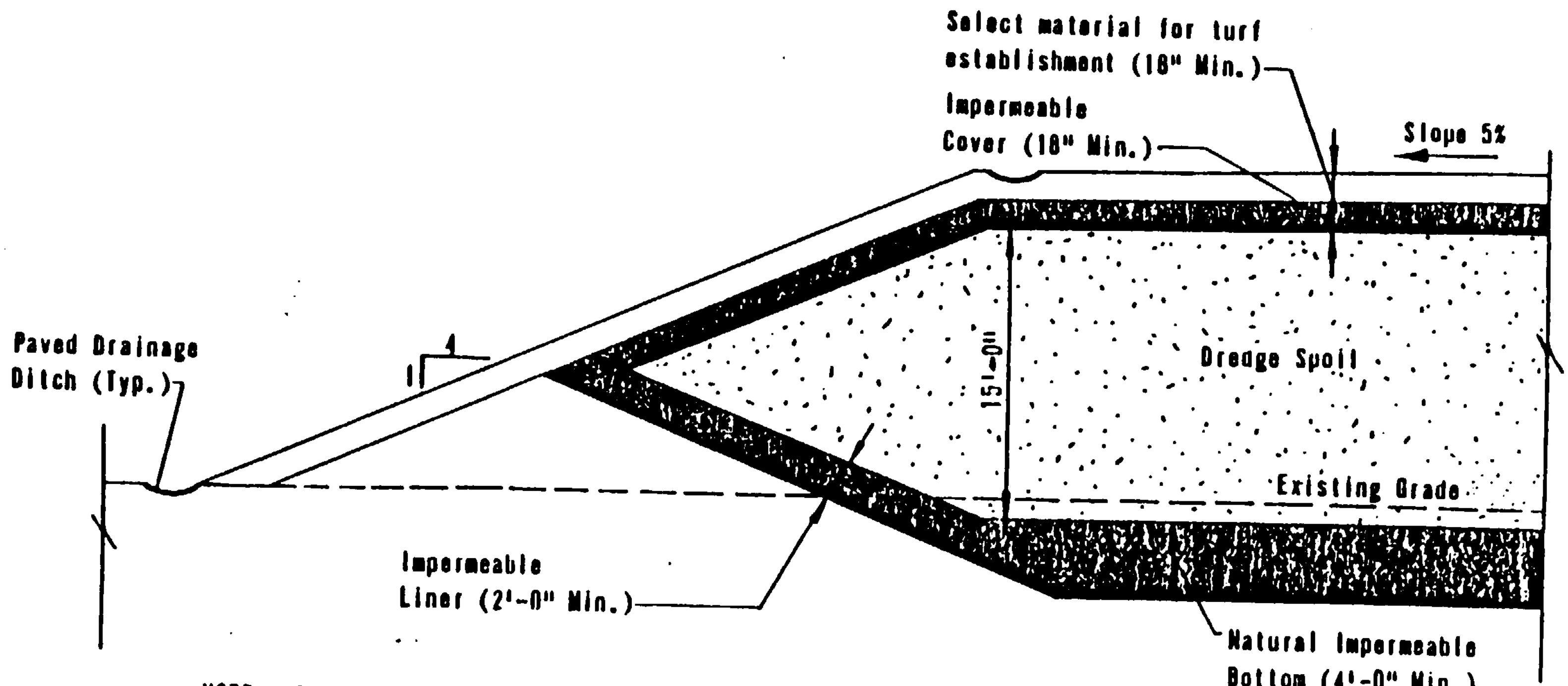


NOTE: Impermeable defined as $K \leq 1 \times 10^{-7}$ cm/sec

MALCOLM PIRNIE, INC

Figure IV-1

TYPICAL DISPOSAL SITE CONSTRUCTION
CLAMSHELL EXCAVATION - MECHANICAL UNLOADING



NOTE: Impermeable defined as
$K \leq 1 \times 10^{-7}$ cm/sec

MALCOLM PIRNIE, INC

Figure IV-2

- Dikes (average height 15 ft) lined with at least 2 ft of impermeable material ($K \leq 10^{-7}$ cm/sec).
- An impermeable cover ($K \leq 10^{-7}$ cm/sec) at least 18 in. thick over the top of the site. This, together with the 5 percent slope given the top of the dredged material will facilitate runoff and minimize the amount of rainfall penetrating the fill.
- A 18 in. layer of select material for turf establishment over the top of the site. This will be seeded and graded and a vegetative cover established to stabilize the site.
- A system of monitoring wells to monitor leachate generation, and collect leachate for treatment, if necessary.

Figure IV-2 shows a sketch of a typical disposal site for a clamshell excavation system. The design is similar to that for a hydraulic disposal site except that only small toe dikes (average height 4 ft) are required, and the height of fill can be increased from 10 to 15 ft.

CHAPTER IV

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Slope, sensitive areas, wetlands, and surface waters: 1:24,000, 7.5 minute quadrangles

	Topographic	Planimetric	LUNR	Wetlands
Hudson Falls	1966	1969	1968	1968/1976
Glens Falls	1966	1968	1968	1968/1976
Fort Miller	1967	1969	1968	1968/1976
Schuylerville	1967	1969	1968	1968/1976
Schaghticoke	1954	1974	1968	1968/1976
Gansevoort	1968	1974	1968	1968/1976
Quaker Springs	1967	1974	1968	1968/1976
Mechanicville	1954	1974	1968	1968/1976
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CHAPTER V

RETURN FLOW TREATMENT

Introduction

Dredging operations generally lose bed materials and their associated contaminants via several mechanisms. These include bed materials that are missed during the dredging process due to inaccuracies in dredge control, suspension of bed materials in the water column due to agitation of the bottom, and loss of dredged material due to leakage or spillage from the dredging or transport mechanism.

The amount of river bed material that is lost is often related to the dredging system used. For instance, hydraulic dredging or pumpout systems use substantial quantities of river water to transport dredged material in slurry form. This transport water inevitably becomes contaminated with suspended solids, and with the pollutants present in the original bed material. For the Upper Hudson the contaminants evaluated include PCB, heavy metals and oxygen demand. State and Federal regulatory agencies require treatment of these waters to meet established water quality levels prior to discharge.

It is the purpose of this chapter to examine various treatment methods for the dredge return waters and to recommend specific, feasible methods for treating these waters to meet the required standards.

This chapter contains the following sections:

- Water Quality Criteria
- Return Water Quality Without Treatment
- Treatment Methods Considered
- Sedimentation
- Filtration - Adsorption
- Barge Mounted Treatment
- Heavy metals
- Oxygen Demand
- Costs
- Evaluation of Treatment Alternatives - Thompson Island Pool
- Ultimate Disposal

Water Quality Criteria

For the Upper Hudson, criteria for maintenance dredging will be established by the DEC as part of the certification procedure. Criteria which have been applied to projects in the past are given in Table V-1.

These criteria do not necessarily apply to the dredging program under discussion here, since the DEC procedure is to establish criteria for each project, on a case by case basis. Nevertheless, the criteria do serve as a useful benchmark for use in evaluating the effectiveness of various treatment alternates.

Return Water Quality Without Treatment

The dredge transport slurry contains the material dredged from the river bottom. Since the objective of any

TABLE V-1

MAXIMUM CONTAMINANT CONCENTRATIONS FOR WATERS IN WATERWAYS AND SPOIL AREA RETURN FLOWS[1]

CHAMPLAIN BARGE CANAL AND HUDSON RIVER[2]

	Maximum Allowable Concentration (μg/l)	
	Water in Waterways	Spoil Area Return Flow
PCB	0.5	10.0
Mercury	2	20.0
Arsenic	50	500
Cadmium	10	100
Chromium	50	500
Copper	200	2000
Nickel	2500	25000
Lead	30	300
Zinc	300	3000
Turbidity	10 Jtu[3]	50 Jtu

[1] From previous DEC certification of DOT maintenance dredging.
[2] Champlain Barge Canal and Hudson River refers to those waters downstream of Lock 7, denoted as either Champlain Canal or Hudson River on Lake Survey Chart 180, Sheet C-1 through C-6.
[3] Jackson turbidity units.

dredging project is to remove this material all dredging systems must include provisions to separate the suspended solids from the transport water, independently of any consideration of the protection of receiving water quality. Systems for the initial removal of suspended solids are not considered "treatment" as the term is used in this chapter.

Typically, the method used to separate transport water from suspended solids is to direct the dredge output to an earthen storage basin or basins where the decrease in velocity causes the suspended material to settle. Storage basins are generally not designed on the basis of overflow rate or detention time, but rather in terms of adequate volume to hold the expected quantity of dredged material. Along with each storage basin, a settling or ponding basin is generally included to remove additional suspended solids prior to discharge.

During previous dredging operations at Bouy 212 and Lock 1, data compiled by the DEC[1,2], indicated the following performance by the storage basins, without polymer:

TABLE V-2

STORAGE BASIN EFFLUENT
TYPICAL PERFORMANCE OBSERVED AT BOUY 212 & LOCK 1

	Lock 1	Bouy 212
Detention Time (min.)	15	45
Influent Suspended Solids (mg/l)	10,000	50,000
Influent PCB (μg/g) dry solids (in situ)	15	100
Effluent Suspended Solids (mg/l)	2000	500
Effluent PCB (μg/l)	40	100

Jar tests conducted by the DEC[1] on typical Hudson River sediments, utilizing detention times of from 1.5 to 2.5 hours, indicate supernatant turbidities ranging from 200 to 2500 Jtu and suspended solids from 150 to 1500 mg per l. Higher supernatant turbidities and suspended solids appear to be associated with a high percentage of silt and clay in the sediment.

Elutriate tests by Malcolm Pirnie, Inc.[3], using Hudson River sediments combined with water at a ratio of 10 parts by weight water to 1 part sediment, indicate that after 2.5 hours settling, without polymer, supernatant quality was as follows:

TABLE V-3

ELUTRIATE TEST RESULTS
SUMMARY

Turbidity	100 to 150 Ntu*
Suspended Solids	100 to 200 mg/l
PCB	Not Measured

* Nephelometric turbidity units

After 18 to 24 hours settling, without chemical addition, supernatant suspended solids were reduced to 20 to 40 mg per l and turbidity to 60 to 80 Ntu.

Based on these data, and allowing for the fact that the storage basins contemplated as part of this project are much larger with consequently longer detention times, it is anticipated that the overflow from the storage basin, would be as follows:

TABLE V-4

RETURN WATER QUALITY
DISCHARGE FROM STORAGE BASIN

Turbidity	500 to 800 Jtu
Suspended Solids	200 to 500 mg/l
PCB	100 to 200 μg/l

Effluent PCB concentrations are based on bed material PCB concentrations between 50 and 150 μg per g.

Comparison of the above values with Table V-1 shows that the discharge from a storage basin will not meet previously established criteria for return flows, without further treatment.

Treatment Methods Considered

PCB is hydrophobic, and therefore highly water-insoluble. Thus it will tend to form aggregations within a body of water and thin films along the surface of the water. PCB is also strongly adsorbed from water onto solid surfaces.

These properties indicate that treatment processes capable of removing suspended and colloidal solids should be effective in removing PCB from water.

A number of treatment alternatives are available for the removal of PCB from wastewater. These include physical-chemical processes such as sedimentation with and without coagulant addition, filtration, adsorption, ultraviolet-assisted ozonation and incineration, as well as biological processes such as microbial decomposition.

While each method was given some consideration, it was found that several, including ozonation and biological treatment, are still in the research and development stage, and are therefore not viable options for a dredging program to be undertaken within the next several years.

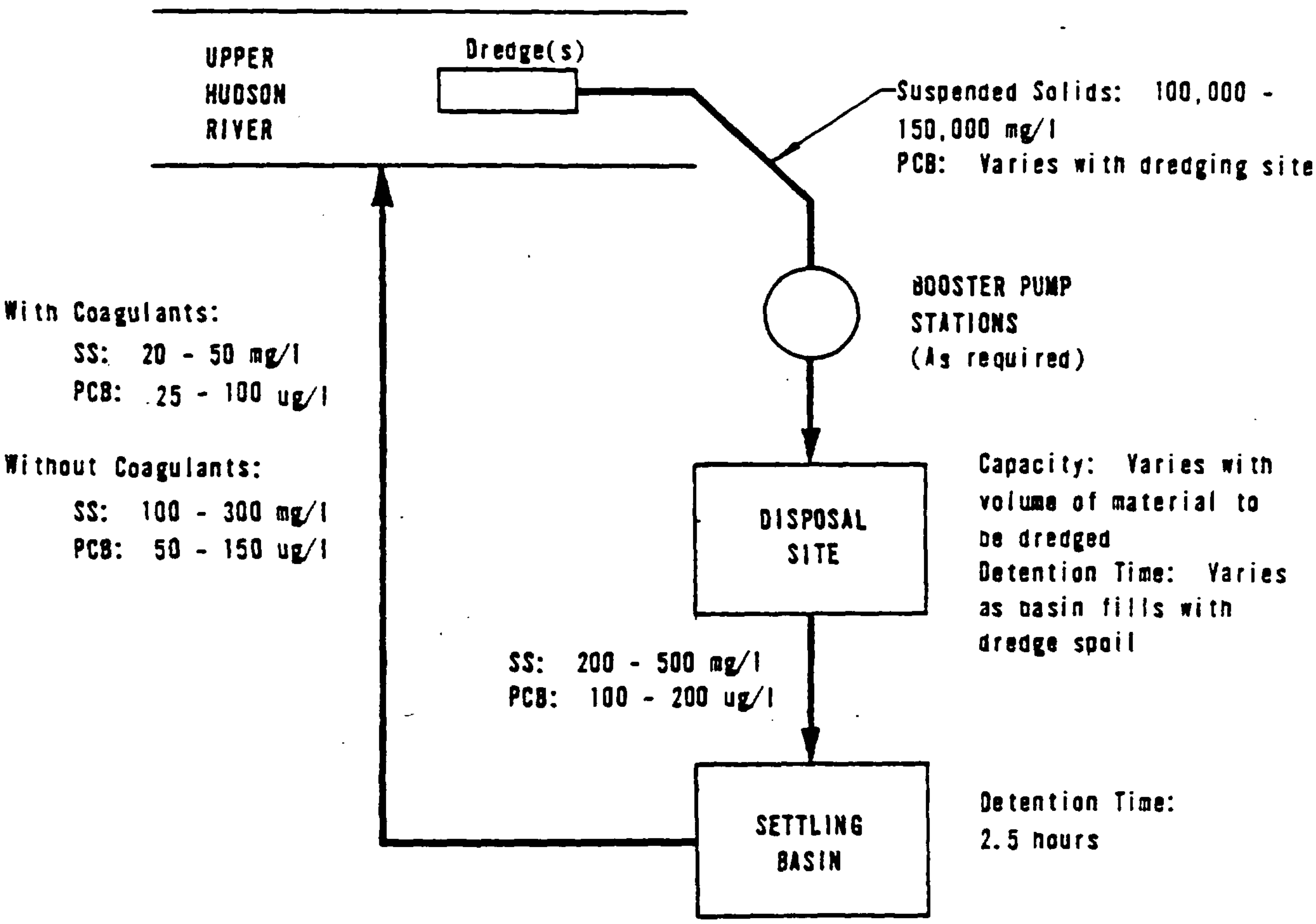
Incineration is economically prohibitive for the very large quantities of dredge slurry expected from a dredging program. The viable alternatives therefore were reduced to sedimentation with and without coagulant addition, filtration, and carbon adsorption.

It should be noted that these alternatives are not exclusive but rather additive. That is, carbon adsorption cannot be used without the preceding steps of sedimentation and filtration to prevent blinding of the carbon units by excessive suspended solids. Similarly, sedimentation must precede filtration to reduce the solids loading to the filters.

Sedimentation

A schematic for a treatment system utilizing sedimentation only is presented in Figure V-1. Settling basin(s) are located adjacent to the storage basin. Basins are constructed of clay lined earthen dikes with a nominal average height of 10 ft. Flow between the storage and settling basins is controlled by a weir box and pipeline; the weir box would provide a convenient point for coagulant addition, if required. Side water depth in the settling basins would be 8 ft, 2 ft lower than in the storage basins, to provide the necessary hydrostatic head.

Based on data compiled by the DEC during earlier dredging operations in Upper Hudson,[2] and the results of lab-



TREATMENT SCHEMATIC
HYDRAULIC DREDGING
SEDIMENTATION

NOTE: Assumed PCB concentration in bed materials 50 to 150 µg per g.

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oratory studies performed by Malcolm Pirnie, Inc.[3], a nominal hydraulic detention time of approximately 2.5 hours has been chosen for the settling basins.

Two types of coagulant have been considered as aids to sedimentation. These are alum (aluminum sulphate) and polyelectrolytes. Laboratory tests by the DEC[2], and confirmatory tests by Malcolm Pirnie, Inc.[3], indicate the addition of either alum or polyelectrolytes can be expected to enhance sedimentation and improve effluent quality with respect to turbidity, suspended solids and PCB.

The choice between alum and polyelectrolyte is primarily an economic one depending on such considerations as the availability and cost of the chemical, case of handling, handling and storage costs, and cost of feed equipment. Polyelectrolytes are generally more expensive than alum but are effective in much smaller quantities and are, therefore, easier to handle, store, and feed. In addition, the resulting sludge quantities are greatly reduced.

Table V-5 shows the expected performance of the settling basin, with and without the aid of coagulants.

TABLE V-5

SETTLING BASIN EFFLUENT

	Without Coagulants	With Coagulants
Turbidity (Jtu)	200-400	30-60
Suspended Solids (mg/l)	100-300	20-50
PCB (μg/l)	50-150	25-100

Effluent PCB concentrations are based on bed material PCB concentrations of 50 to 150 μg per l.

Data obtained by the DEC using bed material from Lock 1 indicate that coagulation followed by fifteen minutes, sedimentation in a lagoon produced an effluent with a PCB concentration of less than 10 μg per l. The initial Lock 1 sediment PCB concentration was 15 μg per g. Using sediment from Bouy 212 with an initial PCB concentration of 100 μg per g, the lagoon effluent PCB concentration after 45 minutes settling with coagulant addition was 50 μg per l. It would appear from these results, that, other factors being equal, the efficiency of performance of the sedimentation basin relative to PCB removal, is related to the initial PCB concentration in the sediment.

Preliminary data indicate that average PCB concentrations in the Upper Hudson range from 10 to 20 μg per g in the Federal Dam to Lock 1 pool, to over 50 μg per g in the

Thompson Island Pool. In addition, it is possible that a dredging program might be confined to areas of higher than average PCB concentration ("hot spots"). Based on the expected range of bed material PCB concentrations, this data suggests that sedimentation with coagulant addition cannot be relied upon to meet previous applied standards for PCB effluent concentrations.

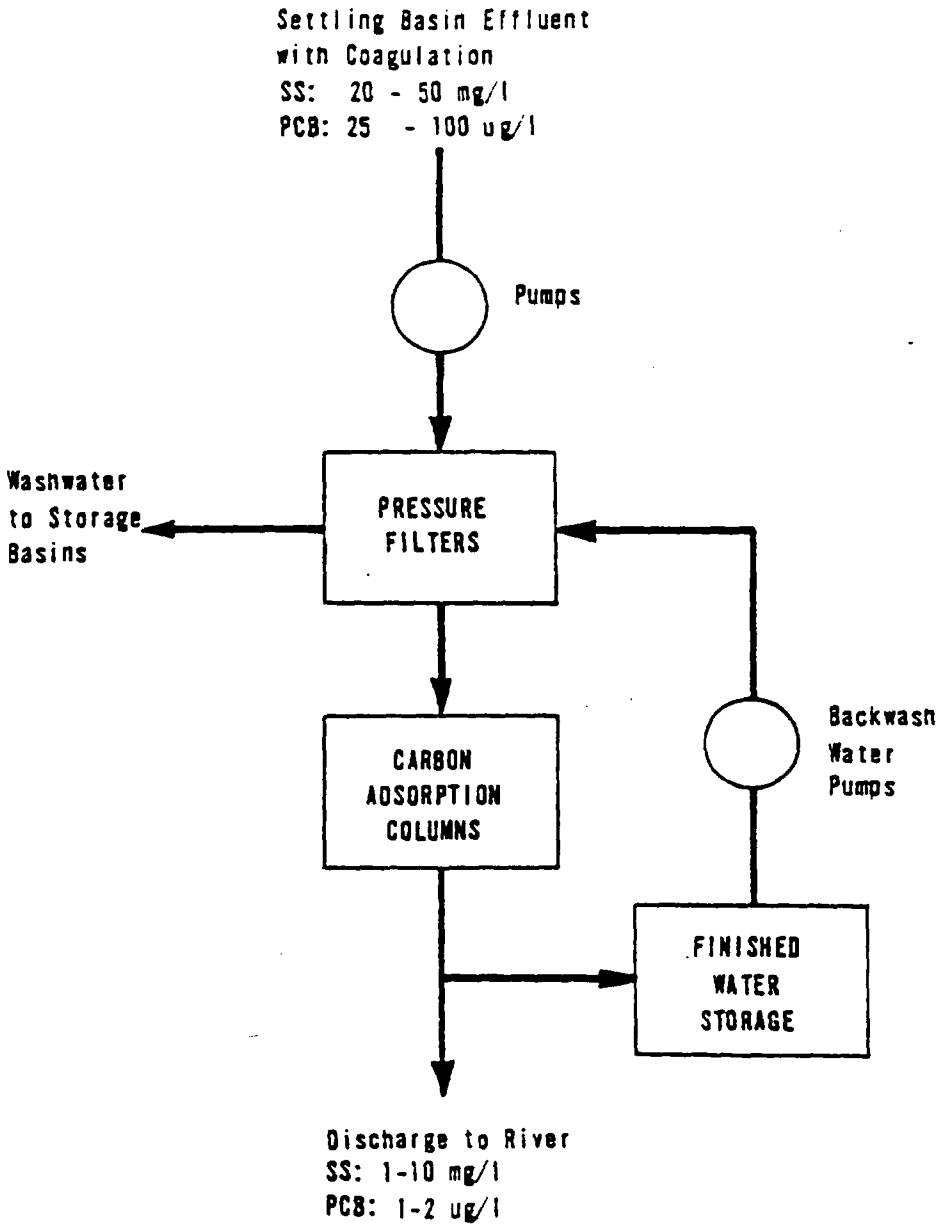
Laboratory tests performed by Malcolm Pirnie, Inc., using fine grained sediment from the Thompson Island Pool with a PCB concentration of 246 μg per g, indicate that, after filtration through a 0.45 micron filter, filtrate PCB concentrations may remain as high as 100 to 150 μg per l.[3] It should be noted that the high after filtration turbidities measured in these tests may indicate exceptional soluble PCB levels in these samples. Nevertheless, since sedimentation cannot be expected to provide the level of suspended solids removal afforded by a 0.45 micron filter, the Malcolm Pirnie, Inc. results indicate that PCB concentrations as low as 10 μg per l cannot be reliably achieved with sedimentation, even when aided by coagulation.

Filtration-Adsorption

Figure V-2 shows a schematic diagram for a filtration-carbon adsorption system which could be added to the treatment system after the settling basin to reduce PCB and suspended solids levels in the return water further, before discharge to the river.

Filters are required ahead of the carbon adsorption units to prevent clogging of the carbon units with suspended solids. The filters are dual media (anthracite on sand) pressure filters designed for an operating pressure of 15 psi (maximum rated pressure 75 psi) and a loading rate of 4 gals per minute per sq ft. Since these are pressure filters, pumps will be required to pressurize the settling basin effluent before filtration.

The filters are followed by carbon adsorption units sized to provide a 15 minute contact time and an adsorption capacity of 0.5 lbs of PCB per 100 lbs of carbon. Carbon adsorption is most effective in removing compounds such as PCB, which have a high molecular weight, are non-polar, and are relatively insoluble in water. Because of the low usage rate (one carbon charge will be adequate for a full dredging season) it has been assumed that the carbon will be used until its capacity is exhausted and then disposed of by incineration or landfill. It is also possible to use thermal regeneration for this activated carbon. Thermal regeneration would require the use of an afterburner for the destruction of PCB in the exhaust gas. Careful monitoring



TREATMENT SCHEMATIC
CARBON ADSORPTION

NOTE: Assumed PCB concentration in bed materials 50 to 150 µg per g.

for residual PCB in the exhaust as well as the regenerated carbon is also required.

Carbon adsorption has been used successfully for PCB removal in several instances, including cleanup of the PCB spill on the Duwamish River,[5] and treatment of the discharges by General Electric.

Based on this experience, and on discussion with vendors of this equipment,[7] performance of the filtration-carbon adsorption system is expected to be as presented in Table V-6 below:

TABLE V-6

FILTRATION-CARBON ADSORPTION SYSTEM
EFFLUENT WATER QUALITY

	Filtration	Filtration-Adsorption
Turbidity (Jtu)	1-10	1-5
Suspended Solids (mg/l)	1-10	1-5
PCB (μg/l)	20-80	<1-2

Effluent PCB concentrations are based on bed material PCB concentrations of from 50 to 150 μg per l.

Comparison with Table V-5 indicates that filtration-adsorption would remove in excess of 95 percent of PCB remaining after coagulation and sedimentation. No currently available technology can achieve lower PCB effluent concentrations.

Barge Mounted Treatment

The foregoing discussion assumes the treatment units will be based on land adjacent to the disposal site or sites. Treatment of dredge return water on barges located close to the dredging site has also been evaluated. In this system, barges will be modified and used as sedimentation basins. Such a system would permit partial dewatering of the hydraulically dredged material at the dredging site, and would make barging the dewatered material to distant disposal sites practical and more economic, by reducing the volume of material to be barged. This would do much to make hydraulic dredging feasible for sections of the river where there are no nearby disposal sites, since pipeline transport of dredged material over long distances is expensive.

Although the scheme outlined above seems plausible, examination indicated that it is not feasible.

Heavy Metals

Heavy metals in the Upper Hudson are generally bound to settleable particulate matter[8], although under certain conditions soluble metal sulfides may be formed. Table V-7 shows bed material heavy metal concentrations for six locations in the Upper Hudson.

TABLE V-7

BED MATERIAL HEAVY METAL CONCENTRATIONS

LOCATION	Concentration in µg/g								
	As	Cd	Cr	Cu	Pb	Hg	Ni	Ag	Zn
Fort Edward[1]-East Channel (RM 194.2 - 194.3)	ND	0.78	9.1	21.2	18.2	0.17	7.4	NM	50.6
		1.0	12.9	18.9	26.7	0.11	8.7		53.2
		0.95	7.7	16.1	19.2	0.10	10.2		52.8
West Channel (RM 194.3 - 194.4)	ND	0.46	8.4	19.0	18.5	0.06	6.9	NM	46.3
		0.76	23.7	29.9	77.5	0.10	9.9		57.8
Bouy 214 (RM 192.4)[2]	2.1	1.1	255	35	150	NM	16.5	NM	150
Thompson Island Pool[2] (RM 188.4)	1.9	27	450	52	375	NM	24	NM	245
Moses Kill (RM 189.1)[3]									
50 Barrel Sample	4	16	560	100	440	0.1	40	26	360
40 Barrel Sample	4	35	825	150	840	1	41	125	680
Northumberland (RM 183.5)[2]	1.2	4.4	42	3.2	180	NM	NM	NM	180
Bouy 212 (RM 192.3)[4]	NM	6.0	27	25	77	NM	NM	NM	88

ND = None Detected, NM = Not Measured

[1] Malcolm Pirnie, Inc., "Environmental Assessment-Maintenance Dredging Champlain Canal, Fort Edward Terminal Channel", p.III-21, (1977)

[2] Tofflemire, T.J., DEC, "Preliminary Report on Sediment Characteristics and Water Column Interactions Relative to Dredging the Upper Hudson River", (1976)

[3] General Electric Corp., Materials Characterization Branch

[4] Tofflemire, T.J., DEC, "Bouy 212 Dredging-Update and Conclusions", Memorandum to Mr. Mt. Pleasant, (January 1977)

Data compiled by the DEC during Bouy 212 dredging operations[9], presented in Table V-8, indicate that chemical coagulation followed by sedimentation reduced effluent heavy metal concentrations to below previously applied State certification standards for disposal area return flows.

TABLE V-8

RETURN WATER HEAVY METAL CONCENTRATIONS
AFTER COAGULATION AND SEDIMENTATION
BUOY 212 DREDGING RESULTS

Metal	Concentration (μg/l)
Arsenic	20
Cadmium	20 to 40
Copper	50 to 190
Lead	100 to 200
Zinc	50 to 700
Chromium	50 to 100

Inspection of Table V-7 indicates that the bed material heavy metal concentrations at Bouy 212 may be lower than typical for the Upper Hudson.

Laboratory jar tests conducted by the DEC[10] using river bed materials from three locations are summarized in Table V-9. The bed material heavy metal concentrations from these locations are believed to be more typical of the Upper Hudson than the samples from Bouy 212. These data indicate that, with the exception of cadimum, chemical addition, flocculation, and 1.5 hours of settling were adequate to

TABLE V-9

JAR TEST RESULTS [1]
SUPERNATANT HEAVY METAL CONCENTRATIONS [2]

Location	Concentration in µg/l						
	As	Cd	Cu	Pb	Zn	Cr	Ni
Thompson Island Pool (RM 188.5)	<200	200	<50	100	70	<100	50
Thompson Island Pool (RM 188.5)	<200	200	<50	100	440	<100	50
Bouy 214 (RM 192.4)	<200	200	<50	100	50	<100	50
Route 4 Bridge (RM 183.5)	<200	200	<50	100	<60	<100	<50
Previous Certification Standards	500	100	2000	300	3000	500	25,000

[1] Tofflemire, T.J., DEC, "Preliminary Report on Sediment Characteristics and Water Column Interactions Relative to Dredging the Upper Hudson River For PCB Removal", Tables 6 and 11 (April 1976)

[2] After 1.5 hours settling, with alum (125 mg/l) or polymer (15 to 20 mg/l) added. Sediment to water ratio (weight basis) between 1:7.4 and 1:14.5.

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produce supernatant heavy metal concentrations that satisfied previous DEC certification standards. While it is not known why cadmium levels observed in these jar tests exceeded those observed during the dredging at Bouy 212, it is believed that the Bouy 212 values are more indicative of the results to be expected during an actual dredging program.

The jar test results suggest that supernatant heavy metal concentrations are not directly dependent on initial bed material heavy metal concentration, at least within the range of concentrations observed between the four samples tested. It is inferred from this that, even if areas of higher than average heavy metal concentrations are encountered during a dredging program, and if sedimentation aided by coagulation is used for return flow treatment, the effluent quality with respect to heavy metal concentration will not deteriorate and will meet the previously established DEC certification standards.

Additional DEC elutriate tests, on material collected from the Thompson Island Pool, are currently under way, and may further clarify these questions in relation to heavy metals.

Oxygen Demand

Benthic oxygen demand is known to exist and gas bubbles have been observed in the Upper Hudson indicating a river bottom sediment biologically active in places. It is expected that when suspended in the water column during dredging, the organic material and reduced chemical compounds will exert an oxygen demand and lower the ambient dissolved oxygen levels. There are no data on the oxygen demanding characteristics material of dredged material although is cases where dredged material is disposed of in a body of water it is not unusual to aerate it to satisfy its immediate oxygen demand.[11] The existing DEC and Corps of Engineers (COE) permit requirements do not include evaluation of oxygen demand during dredging operations.

Oxygen demand is not expected to be a problem during dredging in the Upper Hudson considering the high ambient dissolved oxygen levels and the relatively small quantities of material expected to be lost. It is suggested, however, that a limited number of BOD determinations be included in any detailed design of remedial programs.

Costs

Treatment costs are dependent on the dredging system used since different dredging systems produce different quantities of wastewater. For this chapter, four sizes of treatment system were considered, as this is the likely range of sizes for dredging systems:

- A 2 mgd system, adequate to treat the wastewater produced by a clamshell excavation/mechanical unloading system. This would include barge pump-out, as well as rainfall and runoff from both the unloading and disposal sites.

- A 6.7 mgd system, adequate to treat the wastewater produced by a 12-in. hydraulic dredge.

- A 12.6 mgd system, adequate to treat the waste-water produced by a 16-in. hydraulic dredge.

- A 38 mgd system, adequate to treat the wastewater produced by three 16-in. dredges, all using the same disposal site.

In each case, the treatment systems are designed to treat the average flow produced by the dredging system, not the peak flow, since it is assumed that the dredged material storage basins can be used as flow equalization basins by manipulating weir heights and water depths.

Table V-10, presents capital, and one-season operating costs for treatment systems consisting of sedimentation with coagulant addition.

TABLE V-10

TREATMENT COSTS
SEDIMENTATION WITH COAGULANT ADDITION
COSTS IN MILLION $

Flow	Capital Cost	One Season Operating Cost
2.0 mgd	0.17	0.05
6.7	0.14	0.10
12.6	0.16	0.16
38.0	0.23	0.44

All costs are current (1978) costs. Capital costs include construction of an unlined earth dike sedimentation basin, purchase of chemical feed equipment, and miscellaneous appurtenances such as weirs, piping and valves. Contingencies, contractors' overhead and profit are not included, but are included in total system cost estimates presented in chapters VI and VII. The 2 mgd system applies to clamshell excavation with mechanical unloading only. Capital costs are higher than for larger treatment systems because certain pumping and other equipment is required as part of the mechanical unloading system, and is included here.

Costs for filtration-adsorption treatment systems are presented in Table V-11. These costs are in addition to the costs for sedimentation which must be used prior to carbon adsorbtion. Costs are based on 1977 costs of equipment and material, escalated by 6 percent to 1978 to accommodate expected price increases due to inflation. Operating costs are for one dredging season.

Table V-11 assumes that the State would have the treatment facilities designed and built in the conventional public works manner, and would contract separately for the operation of these facilities. In this case the equipment would be owned by the State and could be salvaged and resold

TABLE V-11

FILTRATION-ADSORPTION TREATMENT
COSTS IN MILLION $

A. Filtration

Flow	Equipment Cost	Installation Cost	Installed Cost	Salvage Value	Net Installed Cost	One Season Operating Cost
2.0 mgd	0.50	0.15	0.65	0.25	0.40	0.12
6.7	1.40	0.39	1.79	0.70	1.09	0.31
12.6	2.17	0.65	2.82	1.08	1.74	0.52
38.0	4.50	1.30	5.80	2.20	3.60	1.75

B. Carbon Adsorption

Flow	Equipment Cost	Installation Cost	Installed Cost	Salvage Value	Net Installed Cost	One Season Operating Cost
2.0 mgd	0.25	0.10	0.35	0.12	0.23	0.23
6.7	0.60	0.21	0.81	0.30	0.51	0.59
12.6	0.93	0.35	1.28	0.42	0.86	0.98
38.0	1.95	0.70	2.65	1.00	1.65	3.25

at the end of the dredging season to defray part of the costs.

Another possibility is the "full service" option under which a contractor-manufacturer would furnish, install, and operate a filtration-adsorption treatment system for a complete dredging season. One company, has expressed preliminary interest in furnishing such a system, but only for the 2.0 and 6.7 mgd sizes. The budget price for a 2.0 mgd filtration adsorption system, for one season, is $500,000, as compared with $980,000 if the State owns the equipment itself. For the 6.7 mgd size the full service cost would be $1,400,000 as compared with $2,500,000 for State ownership. For these sizes, the full service option is clearly less expensive and is recommended.

Table V-12 presents cumulative costs for three levels of treatment: sedimentation with coagulant addition, sedimentation with coagulant addition plus filtration, and sedimentation with coagulant addition, plus filtration, plus carbon adsorption. These costs are calculated on the same basis as Tables V-10 and V-11. For the 2.0 and 6.7 mgd sizes costs for the full service option are shown in parenthesis.

TABLE V-12

CUMULATIVE TREATMENT COSTS IN MILLION $

Flow	Sedimentation with Coagulant Addition	Sedimentation with Coagulant Addition plus Filtration	Sedimentation with Coagulant Addition, plus Filtration, plus Carbon Adsorption [1]
2.0 mgd	0.22	0.74	1.20 (0.72)
6.7	0.24	1.64	2.74 (1.64)
12.5	0.32	2.58	4.42
38.0	0.67	6.02	10.92

[1] Costs shown in parenthesis assume full service option selected for filtration-adsorption.

Evaluation of Treatment Alternatives (Thompson Island Pool)

Table V-13 summarizes treatment costs and performance for two dredging systems. One is a clamshell excavation-mechanical unloading system with a nominal return flow of 2 mgd. The second is a hydraulic system utilizing three 16-in. dredges, with a return flow of 38 mgd. Both dredging systems are appropriate in size for dredging the Thompson Island Pool in one dredging season. These and other dredging systems are discussed in more detail in Chapter VI.

Examination of Table V-13 indicates the following:

- Higher levels of treatment are much more expensive for hydraulic dredging than for clamshell, because of the greater quantities of return flow.
- The previously established certification standard for PCB concentration in the return flow of 10 μg per l can be met only with carbon adsorption.
- The PCB quantities lost in return flows only, under any combination of treatment level and dredging alternatives, are not large. The alternate losing the largest quantity is hydraulic dredging with treatment by sedimentation with coagulant addition. Less than 3 percent of the total quantity in the Thompson Island Pool would be lost in the return flow using this alternate.

Ultimate Disposal

Of the various possible methods for the complete destruction of PCB only incineration is adequately proven at this time to be considered for inclusion in a remedial program for the Upper Hudson River.

TABLE V-13

TREATMENT COST-EFFECTIVENESS
THOMPSON ISLAND POOL

A. Clamshell Excavation - Mechanical Unloading (Return Flow = 2 mgd)

Treatment	Treatment Cost (Million $)	Effluent PCB Conc. (μg/l)	Effluent PCB [1] (lbs)	% of Total in Thompson Island Pool [2]	Treatment Cost/lb Removed in Treatment
None	0	100-200	200-400	0.2-0.4	0
Sedimentation with Coagulant Addition	0.22	25-100	50-200	<0.1-0.2	$1300
Sedimentation with Coagulant Addition plus Filtration	0.74	20-80	40-160	<0.1-0.2	$3700
Sedimentation with Coagulant Addition, plus Filtration, plus Carbon Adsorption	0.72 [3]	1-2	2-4	<0.1	$2400

[1] Based on 4.8 dredge months, 25 working days per month
[2] Total PCB in Thompson Island Pool 100,900 lbs.
[3] Cost for filtration-adsorption is less than for filtration, because full service option is available for this alternative.

TABLE V-13 (Continued)

TREATMENT COST-EFFECTIVENESS
THOMPSON ISLAND POOL

B. Hydraulic Dredging (Return Flow 38 mgd)

Treatment	Treatment Cost (Million $)	Effluent PCB Conc. (μg/l)	Effluent PCB (lbs)[1]	% of Total in Thompson Island Pool[2]	Treatment Cost/lb Removed ($/lb)
None	0	100-200	2900-5800	3-6	0
Sedimentation with Coagulant Addition	0.67	25-100	720-2900	0.7-3	$ 260
Sedimentation with Coagulant Addition plus Filtration	6.02	20-80	580-2300	0.6-2	$2100
Sedimentation with Coagulant Addition plus Filtration plus Carbon Adsorption	10.92	1-2	30-60	<0.1	$2500

[1] Based on 10.0 dredge months, 25 working days per month
[2] Total PCB in Thompson Pool 100,900 lbs.

In order to be effective for PCB destruction, incineration requires a temperature of 2200°F and a residence time of 2 to 3 seconds. Commercial facilities providing for the destruction of PCB contaminated wastes by incineration exist, and charge between $0.05 and $0.10 per lb for this service[4].

The total quantity of bed material on the Upper Hudson is 14.5 million cu yd. If this material were dredged and then dewatered to its in situ density of 65 lbs per cu ft, this would be equivalent to 25 billion lbs to be disposed of by incineration. Assuming a disposal unit cost of $0.10 per pound, the total disposal cost would be in excess of $2.5 billion dollars for incineration only, not including dewatering. Even if reduced by economies of scale, the cost appears excessive.

Although complete PCB destruction does not seem economically feasible at this time, if the contaminated material is removed and placed in contained disposal sites, it would be possible to return in the future, and process this material for ultimate disposal.

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CHAPTER VI

ALTERNATIVE SYSTEMS FOR TOTAL PCB REMOVAL

Introduction

As used in this chapter, total removal means dredging, bank to bank, the entire Upper Hudson from the Federal Dam at Troy to Lock 7 at Fort Edward, a distance of 34.5 miles, to a minimum depth of 24 in. Due to inherent inaccuracies in the dredging process it would be necessary to allow for a overcut of 12 in. in the dredging; thus the pay limit, and therefore the expected removal, would be 36 in. It is recognized that depth of PCB contamination in many pools is less than 24 in. Nevertheless, limitations of currently available dredging technology do not permit reliable removal if a shallower cut is required. Dredging quantities for the Upper Hudson, based on 36-in. removal, are tabulated in Table VI-1.

It can be reasonably expected that a dredging program as described above would remove virtually all the contaminated bed materials from the Upper Hudson. However, it should be noted that dredging, by its very nature, is not a precise or complete process. Thus, although this is as complete a dredging program as can reasonably be conceived, it must still be expected that some contaminated bed

TABLE VI-1

UPPER HUDSON RIVER
DREDGING QUANTITIES FOR TOTAL REMOVAL

Pool	Net Area (10^6 sq ft)	Bed Material Coverage (%)	Effective Area (10^6 sq ft)	Removal Depth[1] (in.)	Removal Volume (10^6 cu yd)
Federal Dam	24.4	80	19.5	36	2.18
Lock 1	17.4	80	13.9	36	1.54
Lock 1	13.7	80	11.0	36	1.22
Lock 3	14.4	80	11.5	36	1.28
Lock 4	53.6	80	42.9	36	4.77
Lock 5	10.7	80	8.5	36	0.94
Lock 6	9.5	80	7.7	36	0.86
Thompson Island Dam	19.4	80	15.5	36	1.72
Total	163.1		130.5		14.51

[1] 24-in. required removal plus 12-in. allowable overcut.

materials, and therefore some PCB will be missed in the dredging process or lost through spills or other mishaps. In other words, there is no remedial program which can be expected to remove 100 percent of the PCB from the Upper Hudson.

A total removal program, as discussed in this chapter, eliminates the need for a complete knowledge of PCB concentrations over the 3800 acre area of the Upper Hudson. It also eliminates the need for a decision as to what level of PCB concentration would be safe to leave in the river. These two factors make planning and administering such a program considerably simpler than for a program of partial removal. However, as this chapter will show, a total removal program requires dredging and disposing of very large quantitites of bed materials, and the expenditure of large sums of money.

This chapter contains the following sections:

- Dredging Systems
- Disposal Area Requirements
- Other Systems Considered
- Alternatives Considered - Thompson Island Pool
- Dredge Performance
- Alternatives Considered - Upper Hudson River

- Disposal Site Location
- Cost Comparison - Upper Hudson River
- Summary of Dredging System Cost/Performance

Dredging Systems

In Chapter III various dredging systems currently available were discussed. For the job at hand four systems were considered suitable and were evaluated in detail. These included:

- 16-in. hydraulic cutterhead dredge
- 12-in. hydraulic cutterhead dredge
- Clamshell excavation with hydraulic barge unloading
- Clamshell excavation with mechanical barge unloading

16-Inch Hydraulic Cutterhead Dredges

This system would consist of a number of dredges each discharging via an individual pipeline directly to a disposal area. Booster stations would be included along each pipeline as required. In some cases several dredges would share a single disposal area.

Sixteen-inch dredges are readily available in the northeastern United States. While it might be possible to improve the economics of the program somewhat by using 20-in. dredges, such dredges are generally not as readily available. Still larger dredges (24-in. and above) would require extensive alterations to pass through locks and under bridges to reach the Upper Hudson. In addition, larger dredges require greater minimum depths for operation, which hampers their ability to dredge in shallow water.

A 16-in. dredge generally utilizes a cutter with a diameter of approximately 5 ft. When excavating in a bank of 2 to 3 ft, as required for this job, the cutter is not buried, and very little of the cut material will escape the suction flow. This, coupled with the type of material involved and the shallow height of bank (which minimizes bank caving) should result in an operation relatively free of turbidity and resuspension of material. On the other hand, the shallow bank, coupled with the weight of the material, reduces the effective output of the dredge. An additional measure which can be used to reduce dredge induced turbidity and attendant PCB loss is to limit the speed at which the cutter may be turned. This also limits production and must be done judiciously.

Like all hydraulic dredges, the 16-in. dredge utilizes substantial quantities of water to transport the dredged material via pipeline to the disposal site. This water must then be treated to remove suspended material and PCB before return to the river. For a single 16-in. dredge a treatment facility with a capacity of about 12.5 mgd would be required.

12-Inch Hydraulic Cutterhead Dredges

This system would be similar to the 16-inch system discussed above, except for the use of smaller dredges.

Twelve inch dredges are readily available and, because of their smaller size, can be more accurately controlled than larger machines. Because the job at hand involves the removal of shallow depths of contaminated material, accurate control is clearly important.

Twelve inch dredges utilize cutters with a diameter of approximately 3 ft - 6 in. so that a large portion of the cutter would be buried in the bed material increasing the probability of material escaping the suction and being resuspended. Again, this can be reduced by limiting the speed of cutter rotation.

Each 12-in. dredge would require a treatment facility with a capacity of approximately 7 mgd.

Clamshell Excavation - Hydraulic Unloading

This system would consist of a number of barge mounted derricks equipped with clamshells for excavation. The clamshells would load the dredged material directly in hopper scows (barges) for transport to the disposal areas.

The requirement to excavate to a depth of 2 ft limits the maximum size of the clamshell which can be utilized to approximately 5 cu yd. While the size of the locks permit passage of hopper scows up to approximately 1500 cu yd, this analysis is based on 1000 cu yd scows for reasons of availability. Because of the 12-foot draft required by the hopper scows when fully loaded, there are areas to be excavated in shallow water which do not permit the scows to get close enough to the bank for direct loading by the excavating clamshell. For these areas, the use of hopper-conveyor barge (see Fig. VI-1) is suggested; this will allow the scows to remain in deep water while the clamshell operates in the shallow areas.

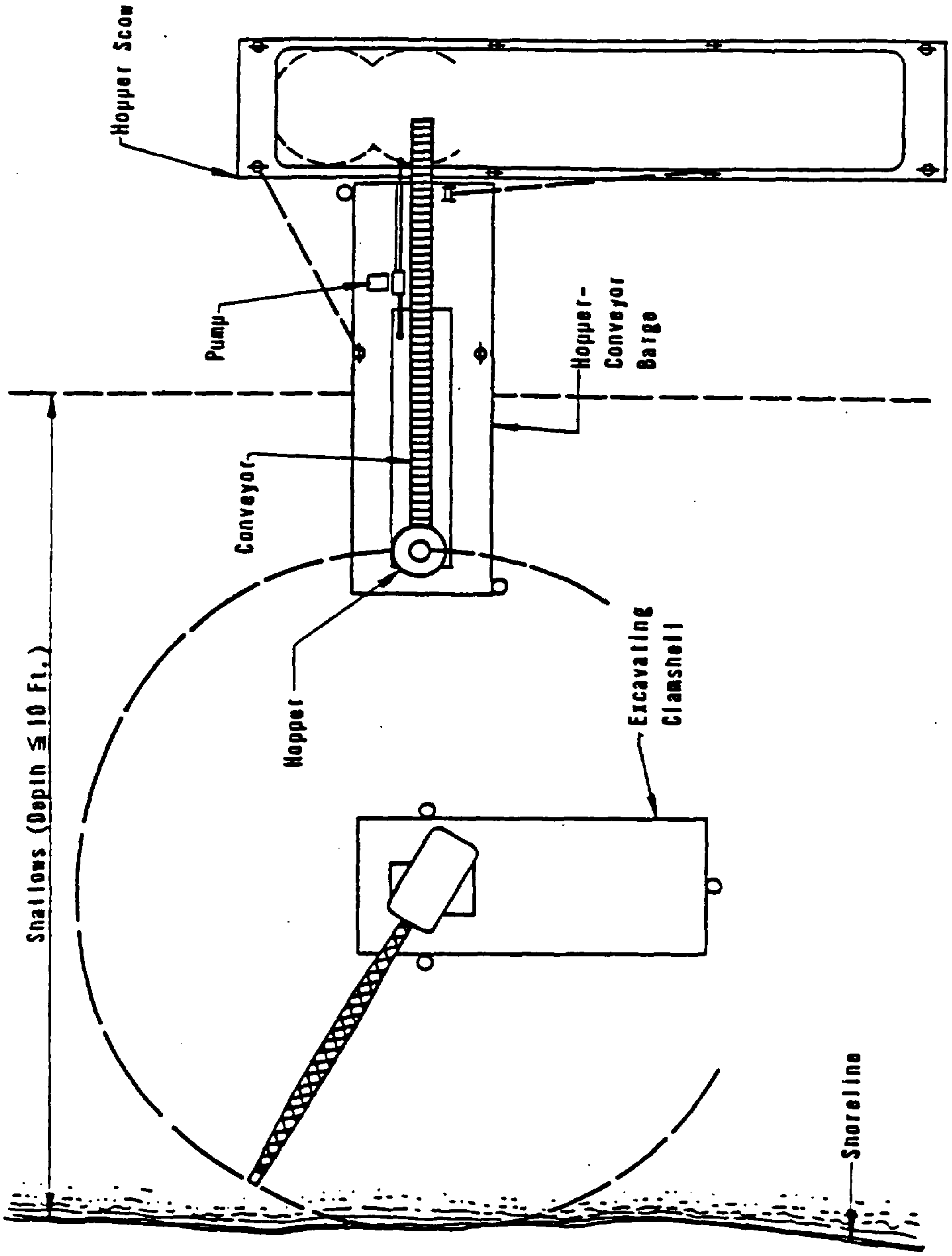
The scows would be moved to the unloading areas by tugs which would also be used to relocate the clamshell barges as required. This analysis assumes that the dredges operating in any one reach would be in close enough proximity to permit the sharing of tug time. A tender tug has also been included to assist the larger tugs at the unloading site.

At the unloading site a hydraulic pump-out system will be used to unload the scows and transport the dredged material, via pipeline, to the disposal area. It will be necessary to resuspend the dredged material using river water, which will, of course, become contaminated with suspended solids and PCB and require treatment before return to the river. For reasons of availability, use of a 27-in. pump-out plant has been assumed for this cost estimate. Such a plant would require a treatment facility with a capacity of 38 mgd. Site preparation for the pump-out plant would require driving piles for mooring the plant and the hopper scows.

<u>Clamshell Excavation - Mechanical Unloading</u>

This system would be the same as the clamshell excavation - hydraulic unloading system discussed above, except that the barges would be mechanically unloaded with land based clamshells. The dredged material would then be placed in a rehandling area and allowed to drain. The rehandling area would be completely paved and diked to prevent leakage or loss of rainwater or barge water. (See Fig. VI-2). Note that the barges will accumulate water during the dredging operation and must be pumped out at the unloading site to prevent overflow when refilled with dredged material.

One advantage of this system compared with hydraulic systems is that large quantities of river water do not become contaminated during the dredging process and, therefore, do not require subsequent treatment. A 2 mgd treatment plant will still be required to handle rainfall at the spoil site, the rehandling area and barge pump-out.



HOPPER-CONVEYOR BARGE SYSTEM

NOT TO SCALE

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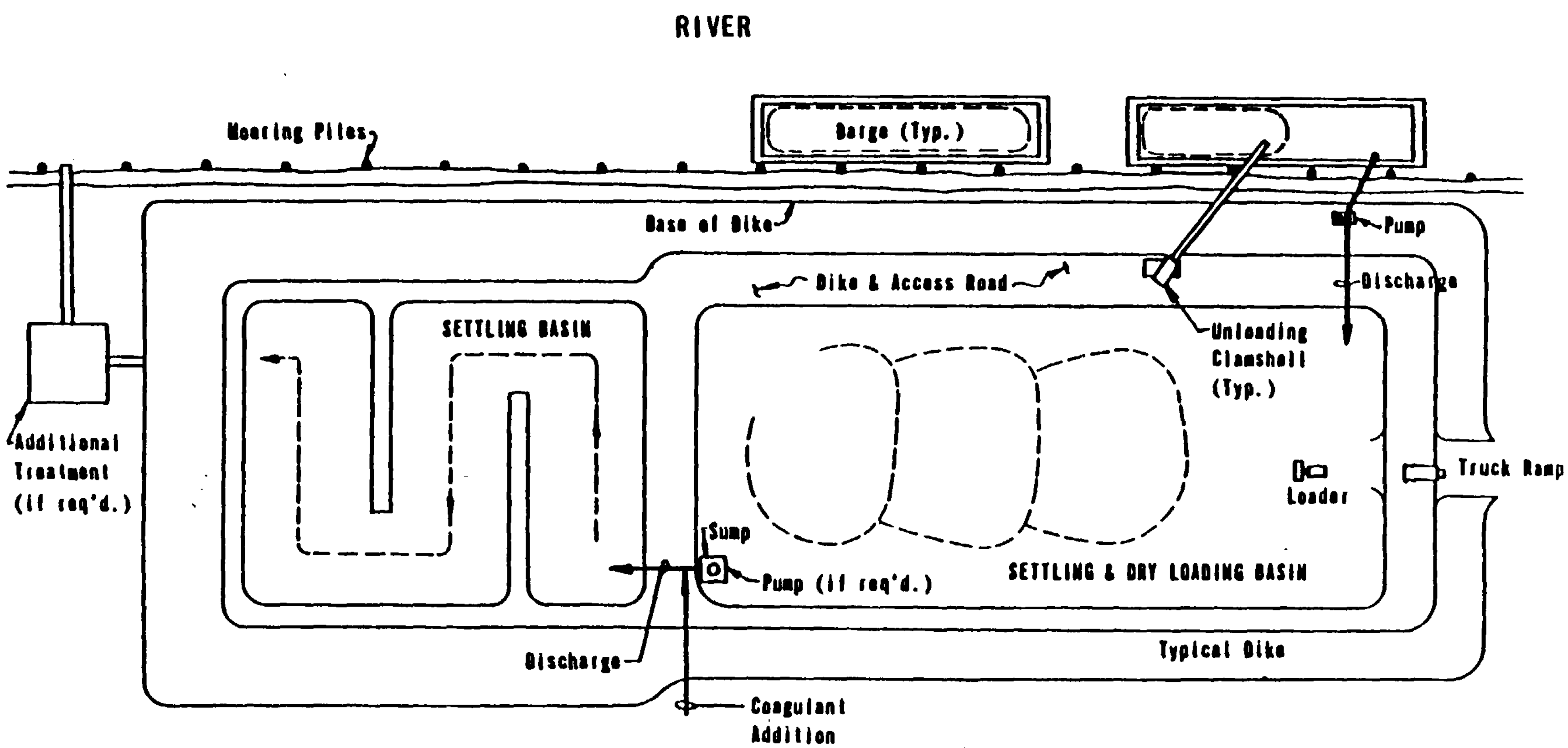

DREDGED MATERIAL REHANDLING AREA

NOT TO SCALE

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The dredged material will be placed in a surge pile at the rehandling area by the unloading clamshells. The material will then be loaded, by ordinary earthmoving equipment, into trucks for transport to the disposal site. This analysis assumes the use of ordinary over the road trucks operating on existing highways, although some economies may be possible by using off highway vehicles operating on specially constructed haul roads.

Disposal Area Requirements

The area of disposal sites required for the Clamshell system is substantially smaller than that required for hydraulic systems for several reasons:

- Fill height can be increased from 10 to 15 ft.
- Only small toe dikes are required to control leachate. This decreases diking costs as well as increasing the usable area at the spoil site.
- No treatment facility is required at the spoil site; leachate can be piped to the rehandling area for treatment. Also, the danger of contamination from leachate can be minimized by covering the contaminated material as it is placed.
- Cross diking and weirs are not required.

The difference in fill height between clamshell and hydraulic systems is an assumption made for estimating purposes. Detailed studies may indicate that the difference in fill heights is not required.

Other Systems Considered

Certain other system were investigated during the course of this study and, while some do offer certain advantages, were found to be unsuitable. These systems are discussed below:

Pneuma - The Pneuma is an compressed air operated submersible pump, and has been used for dredging PCB contaminated material in the United States on at least one occassion[1]. This unit reportedly obtains a high solids content in the dredged slurry and causes very little turbidity while dredging. However, there are only two units available in the United States at this time. Furthermore, since the pump depends on water pressure for loading, it is not effective at water depths less than 12 ft. Also, debris-laden material as is present in the Upper Hudson is quite likely to clog the intake valves. For these reasons the Pneuma was not considered a viable alternative for this project.

Oozer - The Oozer is a Japanese developed air operated dredging pump similar in design to the Pneuma, except that it utilizes a vacuum pump to generate negative suction pressures and thus can be used in shallow water. While the Oozer has been used successfully to dredge high water content mucks ("hedoro") in Japan, it has not been demonstrated to operate effectively on the type of bed material found in the Upper Hudson. Furthermore, the Oozer is not available in the United States at this time.

Mudcat - The Mudcat is a small truck-transportable hydraulic dredge which uses a snow plow type auger to feed material to the pump suction. It is claimed to excavate with minimum turbidity and to produce a high solids concentration on short pipeline runs. However, its small size and consequently low production, and its inability to handle coarse material and debris, make it unsuitable for the Upper Hudson.

Japanese "Clean-up" Dredge - This is a large Japanese hydraulic dredge specially modified for the clean-up of contaminated sediments. Modifications include an underwater pump, a suction feed auger, and shields to prevent gas venting. According to the literature, this dredge has been successful in removing contaminated material with a minimum of dredge induced turbidity. However, this dredge has a relatively low production for its size which raises its unit dredging cost. Furthermore, it is not available in the United States and probably would not be able to handle the coarse materials and debris present in the Upper Hudson River.

Loading Barges Hydraulically - The possibility of using hopper scows, rather than pipelines, to transport hydraulically dredged material was considered, as this method is often cost-effective when pipeline lengths are long. However, this method is only economical if dredged material is allowed to settle in the barges and the excess water overflow. If this is not done the scows can only be filled to 10 or 15 percent of capacity and this destroys the economics of using barges. For the Upper Hudson, since the excess water will be contaminated with PCB, treament will be required before return to the river. The only practical way to accomplish this would be with a floating treatment system which could accompany the dredges and scows as they work their way down the river. The concept of a floating treatment system was investigated and found to be impractical.

Draglines - The use of long boom draglines to excavate shallows from the bank was considered, but rejected, because of the high turbidity and disturbance to trees and private property along the banks.

Drag Scrapers - The use of drag scrapers (Sauerman Scrapers) was considered to drag material from the shallows to deeper water to facilitate the loading of hopper scows. However, this method would result in substantial turbidity and cannot be controlled as accurately as required for this job.

Partial Dewatering of the River - The possibility of dewatering portions of the river, either by opening the canal locks or by removing portions of the dams, was considered. This would lower the water level in the affected pool and expose the shallow areas permitting removal with earthmoving equipment. It was found that during the winter the water level could not be lowered sufficiently to be of much help because of high flows. If the water level was lowered during the summer the canal would have to be closed to navigation, and there would still be a risk of scour from the exposed deposits if heavy rains occured during work period. In addition, the potential saving does not seem to be large as the unit cost of dredging is generally less than the unit cost for dry land earthmoving.

Alternatives Considered - Thompson Island Pool

In order to compare the cost-effectiveness of the four alternative systems discussed above, an estimate of the cost of dredging the Thompson Island Pool, using several alternates of these systems, was prepared. The Thompson Island Pool is located between the Thompson Island Dam at River Mile 188.5 and Lock 7 at River Mile 193.7, and is the northernmost segment of the study area. This pool was chosen for this comparison because it is the most heavily contaminated section of the Upper Hudson and is, therefore, likely to be dredged first.

The following five alternatives were considered for dredging the Thompson Island Pool:

- 16-in. dredges pumping to a single disposal area.
- 16-in. dredges pumping to three disposal areas.
- 12-in. dredges pumping to four disposal areas.
- Clamshell dredges and barge transport with hydraulic pump-out to a single disposal area.
- Clamshell dredges and barge transport with mechanical unloading and truck transport to a single disposal area.

Pertinent details for each of these alternates are summarized in Table VI-2.

TABLE VI-2

THOMPSON ISLAND POOL
COMPLETE REMOVAL
COMPARISON OF ALTERNATIVES CONSIDERED

Alternative 1

Dredge Type:	Hydraulic
Size of Dredges:	16-inch (1500 HP)
Number of Dredges:	3
Size of Boosters:	16-inch (1200 HP)
Number of Boosters:	6
Time Required:	3.6 months
Disposal Area:	Area 10, 133 acres[1]
Effluent Treatment:	38 mgd

Alternative 2

Dredge Type:	Hydraulic
Size of Dredges:	16-inch (1500 HP)
Number of Dredges:	3
Size of Boosters:	16-inch (1200 HP)
Number of Boosters:	3
Time Required:	3.6 months
Disposal Areas:	Area 4, 44 acres Area 8, 44 acres Area 10, 44 acres
Effluent Treatment:	38 mgd

Alternative 3

Dredge Type:	Hydraulic
Size of Dredges:	12-inch (800 HP)
Number of Dredges:	4
Size of Boosters:	12-inch (500 HP)
Number of Boosters:	3
Time Required:	5.0 months
Disposal Areas:	Area 4, 44 acres Area 10, 44 acres Area 5, 22 acres Area 8, 22 acres
Effluent Treatment:	4 at 6.7 mgd

[1] For locations of disposal areas see Plates III and IV

TABLE VI-2
(Continued)

Alternative 4

Dredge Type:	Clamshell
Size of Dredges:	5 cu yd bucket
Number of Dredges:	3
Hydraulic Pump-Out:	1 at 27-inches
Tugs:	2 large, 3 small
Hopper Scows:	6 at 1,000 cu yd each
Hopper Conveyor Barge:	1
Time Required:	4.8 months
Disposal Area:	Area 12, 133 acres
Effluent Treatment:	38 mgd

Alternative 5

Dredge Type:	Clamshell
Size of Dredges:	5 cu yd bucket
Number of Dredges:	3
Rehandling Clamshells:	2 at 6 cu yd each
Tugs:	2 large, 3 small
Hopper Scows:	6 at 1,000 cu yd each
Hopper Conveyor Barge:	1
Time Required:	4.8 months
Disposal Area:	Area 12, 85 acres
Effluent Treatment:	2 mgd

Cost estimates for each of these alternates were prepared, based on the following major assumptions:

- The dredging contractor would be required to remove 24 in. of bed material, bank to bank, over the entire pool.
- Debris and sediment requiring dredging cover 80 percent of the river bottom.
- To allow for inaccuracies in the dredging process, an actual removal of 36 in. (1 ft overcut) has been assumed for a total removal of 1.7 million cu yds.
- The material to be removed is sand and gravel with some silt and wood fragments.
- At least an additional 12 in. of the same material lies below the desired grade. In other words, that there is no ledge rock or stiff clay that would interfere with the dredging process within 48 in. of the top of the bed materials.
- Labor costs are based on the 1978 wage rates in the Local 25 Operating Engineers Agreement.
- Site preparation and restoration costs are based on assumed average conditions. Prior to final design field work and detailed analysis of the best locations for weirs, cross dikes, treatment plants and return water channels will be required.
- Pipeline costs for the hydraulic alternates are shown as part of dredge operating costs and are based on estimated wear at 30 percent of pipe cost. Initial placement of the pipeline is included in mobilization.
- Site preparation costs do not include the cost of an impermeable synthetic liner. As discussed in Chapter IV, such a liner will not be required at the sites selected.

- Annual maintenance and monitoring costs of the disposal site have not been included.

- Spoil area costs and sizing, for the hydraulic alternates, assume that the nature of the dredged material will permit mounding to a substantial height above the average indicated. The cost for a small portable dredge to redistribute the fines has been included.

- It is assumed that there will be no unreasonable delays because of permits, licenses or legal actions. It is assumed that the required lands, easements for return water drainage, pipeline easements, highway crossings and use of highway can be obtained without significant difficulty.

Based on the assumptions above, cost estimates for five alternates and two levels of return flow treatment have been prepared and are presented in Tables VI-2 and VI-3. Detailed cost estimates with sample calculations are presented in Appendix B.

Table VI-3 assumes return flow treatment by coagulation and sedimentation; Table VI-4 assumes this level of treatment plus the addition of filtration-adsorption. For a more complete discussion of the cost and performance of various treatment alternates see Chapter V.

TABLE VI-3

COST COMPARISON
THOMPSON ISLAND POOL
COMPLETE REMOVAL INCLUDING COAGULATION AND SEDIMENTATION TREATMENT FOR RETURN FLOW
COST IN MILLION $

1.72×10^6 cu yd, 100,900 lbs PCB

Item	16-in. Dredges 1 Disposal Area	16-in. Dredges 3 Disposal Areas	12-in. Dredges 4 Disposal Areas	Clamshell Excavation Hydraulic Unloading 1 Disposal Area	Clamshell Excavatio Mechanical Unloadin 1 Disposal Area
Mobilization	0.5	0.5	0.5	0.3	0.3
Site Acquisition	0.3	0.3	0.3	0.3	0.2
Site Preparation	1.9	2.4	2.1	1.9	0.2
Dredging & Transport	5.9	5.0	4.8	5.9	9.9
Site Restoration	3.0	3.0	3.0	3.0	1.9
Dredging Control	0.4	0.4	0.8	0.6	0.6
Return Flow Treatment	0.7	0.7	0.9	0.7	0.2
Subtotal	12.7	12.3	12.4	12.7	13.3
Contingencies @ 20%	2.5	2.5	2.5	2.5	2.7
Engineering	0.6	0.6	0.6	0.6	0.7
Legal & Admin.	0.3	0.2	0.2	0.3	0.3
Total	16.1	15.6	15.7	16.1	17.0

TABLE VI-4

COST COMPARISON
THOMPSON ISLAND POOL
COMPLETE REMOVAL INCLUDING FILTRATION-ADSORPTION
TREATMENT FOR RETURN FLOW
COST IN MILLION $

1.72×10^6 cu yd, 100,900 lbs PCB

Item	16-in. Dredges 1 Disposal Area	16-in. Dredges 3 Disposal Areas	12-in. Dredges 4 Disposal Areas	Hydraulic Unloading 1 Disposal Area	Mechanical Unloading 1 Disposal Area
All Costs, not Including Return Flow Treatment	12.0	11.6	11.5	12.0	13.1
Treatment, Including Filtration-Adsorption	10.9	10.9	6.5	10.9	0.7
Subtotal	22.9	22.5	18.0	22.9	13.8
Contingencies @ 20%	4.6	4.5	3.6	4.6	2.8
Engineering	1.1	1.1	0.9	1.1	0.7
Legal & Admin.	0.5	0.5	0.4	0.5	0.3
Total	29.1	28.6	22.9	29.1	17.6

Examination of Tables VI-3 and VI-4 indicates the following:

- If return flow treatment is limited to coagulation and sedimentation costs for all five alternatives are very close, with a total variation of 8 percent between the highest and lowest.
- If return flow treatment is limited to coagulation and sedimentation the lowest cost alternative is the use of 16-in. hydraulic dredges going to multiple disposal areas. The cost for this alternative is $15,600,000.
- If return flow treatment is expanded to include filtration-adsorption the least cost alternative becomes clamshell excavation with mechanical unloading. Cost for this alternative is $17,600,000.
- The inclusion of filtration-adsorption makes all of the hydraulic dredging and pumpout alternatives considerably more expensive than clamshell excavation with mechanical unloading.

Dredge Performance

The various dredging systems considered have differing performances with regard to the efficiency and completeness of bed material and PCB removal.[3-7] There are three primary areas of PCB loss:

PCB Missed During Dredging - Due to inaccuracies in dredge positioning and depth control, and difficulties with obstructions and debris in the river bed, no dredging system can economically achieve 100 percent removal of the desired bed materials and their associated PCB. For a medium size hydraulic dredge it is estimated that 2 percent of the bed material will be missed in this way.

A clamshell dredge is significantly less effective than a hydraulic dredge in this regard because of the difficulty in repositioning the clamshell bucket after each load-unload cycle. For clamshell excavation it is estimtated that 5 percent of the bed materials will be missed during dredging.

PCB Lost in the Dredging Process - The operation of the cutterhead on a hydraulic dredge generates a plume of suspended bed materials not all of which is ingested by the dredge suction. Because of the pooled nature of the Upper Hudson much of this material will settle and be recaptured by the dredges since the dredging process will proceed from the northern (upstream) end of each pool southward. A fraction of the PCB associated with the suspended materials in the plume will desorb and escape.

The amount of material disturbed or suspended by the dredge is a function of bed material characteristics, cutterhead RPM, speed of dredge swing, and depth of cutting face, as well as other factors. For the Upper Hudson, on the average, it is estimated that a 16-in. dredge would suspend 2 percent of the material dredged. Based on laboratory data, it is estimated that 20 percent of the PCB associated with the bed materials in the plume would desorb or be associated with particulates so fine that they will not readily settle.

A clamshell dredge also generates a plume of suspended material while dredging. A clamshell suspends material by disturbing the bottom when loading, by leakage between bucket leaves imperfectly closed because of debris or coarse sediments, and by washing of material from the top of the bucket while lifting. Other investigators[2] have measured a loss rate of 2.5 percent while dredging in sea water 30 ft deep. For the Upper Hudson, it is estimated that a clamshell would suspend 4 percent of the material dredged, and that, as for the hydraulic dredge, 20 percent of the PCB associated with the suspended bed material would desorb.

<u>PCB Lost in the Return Water</u> - Both a hydraulic dredge and a clamshell dredge using a hydraulic pumpout system use substantial quantities of river water to transport the dredged material via pipeline. The transport water, of course, becomes contaminated with PCB and must be treated prior to discharge to the river. As discussed in Chapter V, two treatment methods are considered: coagulation and sedimentation which will reduce the PCB concentration in the return water to between 25 and 100 μg per l, and filtration-adsorption which will reduce the PCB concentration to between 1 and 2 μg per l.

Other Losses - A potential exists for other, relatively minor, losses during the dredging operations. These include pipeline breakage, spillage, turbidity induced by floating plant movement, and general housekeeping losses. Although care should be taken to minimize all such losses, it is believed that their potential magnitude is small and they have not been explicitly included in the loss estimates.

Table VI-5 summarizes the performance of three dredging systems with regard to PCB losses. The Thompson Island Pool is used as an example considering both treatment alternatives discussed above. This table is based on the estimates and assumptions discussed above and should be regarded as approximate. Nevertheless, while there may be uncertainty with regard to individual values, the table still demonstrates that overall PCB removal effectivness is not very different for the various dredging systems and treatment methods considered. The most effective system (hydraulic dredging including filtration-adsorption return flow treatment) is estimated to remove an additional 6240 lbs of PCB compared to the least effective system (clamshell excavation-hydraulic unloading with coagulation and sedimentation return flow treatment). This is equal to less than 6 percent of the total PCB in the Thompson Island Pool.

TABLE VI-5

PERFORMANCE OF DREDGING SYSTEMS FOR TOTAL REMOVAL
WITH REGARD TO PCB LOSSES
THOMPSON ISLAND POOL

Item	Hydraulic Dredging lbs	Hydraulic Dredging %	Clamshell Excavation With Mechanical Unloading lbs	Clamshell Excavation With Mechanical Unloading %	Clamshell Excavation With Hydraulic Unloading lbs	Clamshell Excavation With Hydraulic Unloading %
Total PCB in Thompson Island Pool	100,900	100	100,900	100	100,900	100
PCB Missed During Dredging	2,000	2	5,000	5	5,000	5
PCB Lost in Dredging Process	400	<1	800	<1	800	<1
PCB Lost in Return Water[1]	2,900	3	200	<1	2,900	3
Net PCB Removal	95,600	95	94,900	94	92,200	91
PCB Lost in Return Water[2]	60	<1	4	<1	60	<1
Net PCB Removal	98,440	98	95,100	94	95,040	94

[1] Assuming treatment by coagulation and sedimentation.
[2] Assuming treatment including filtration-adsorption.

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Alternatives Considered - Upper Hudson River

In considering dredging systems for the complete Upper Hudson, there are three variables to be optimized:

- Dredging/Transport System
- Return Water Treatment Method
- Disposal Site Location

Based on the results of the Thompson Island Pool analysis, the following alternatives were considered for the entire Upper Hudson:

Alternative 1 - Hydraulic dredging, with 16-in. dredges, with pipeline transport to multiple disposal areas.

Alternative 2 - Clamshell dredging, barging, mechanical unloading, and truck transport to multiple disposal areas.

Alternative 3 - Clamshell dredging, barging, mechanical unloading, and truck transport to a single disposal area.

Alternative 3A - Clamshell dredging, barging, mechanical unloading, and conveyor transport to a single disposal area.

Two levels of return flow treatment were considered for each of these 4 alternatives. These were coagulation and sedimentation and coagulation and sedimentation plus filtration adsorption.

Disposal Site Location

Optimization of disposal site location involves conflicting criteria. On the one hand, it is desirable to use the fewest number of disposal sites, one if possible, to minimize acquisition and future monitoring problems. However, costs tend to be minimized by using multiple sites located as close as possible to the dredging site.

In the following analysis, both possibilities have been explored for the clamshell dredging alternates. The single disposal site option was not considered feasible for the hydraulic dredging alternates, because of the excessive lengths of pipelines required.

Cost Comparison - Upper Hudson River

Pertinant details for each of the four systems considered are summarized in Tables VI-6, VI-7, and VI-8.

Cost estimates for each of these systems have been prepared and are presented, with sample calculations, in Appendixes C, D, E and F.

Costs are summarized in Tables VI-9 and VI-10. These cost estimates are based on the same major assumption discussed earlier for the Thompson Island Pool.

Alternative 3A differs from Alternative 3 only in that a conveyor system has been included to transport the dredged material from the unloading to the disposal site.

Dredging quantities are based on 36-in. removal and 80% bed material coverage and are as summarized in Table VI-1. Total quantity is 14.5 million cu yd.

TABLE VI-6

UPPER HUDSON RIVER
COMPLETE REMOVAL
ALTERNATIVE 1 - HYDRAULIC DREDGING

Reach	Dredges	Booster Pump Stations	Months Required	Disposal Areas[1]
1. Federal Dam - Lock 1	3	19	4.6	Area No. 26, 34 Acres
				27, 37
				29, 96
2. Lock 1 - Lock 2	2	24[2]	4.9	33, 41
				34, 51
				36, 28
3. Lock 2 - Lock 3	2	16	3.8	36, 40
				37, 28
				39, 27
4. Lock 3 - Lock 4	2	10	4.0	
				23, 100
5. Lock 4 - Lock 5	6	89[2]	5.0	17, 40
				18, 125
				19, 29
				20, 144
				21, 22
6. Lock 5 - Lock 6	2	2	3.0	43, 75
7. Lock 6 - Thompson Is. Dam	2	3	2.7	9, 69
8. Thompson Is. Dam - Lock 7	3	6	3.6	10, 133

[1] For Location of Disposal Areas See Plates III and IV.
[2] Because of the amount of equipment required, these reaches would be divided into several subreaches and dredged over several seasons.

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TABLE VI-7

UPPER HUDSON RIVER
COMPLETE REMOVAL
ALTERNATIVE 2 - CLAMSHELL EXCAVATION
WITH MECHANICAL UNLOADING

Reach	Dredges	Scows	Rehandling Clamshells	Tugs Large	Tugs Small	Months Required	Disposal Areas[1]
1. Federal Dam - Lock 1[2]	4	12	3	7	4	4.5	Area No. 26, 12 Acres 29 96
2. Lock 1 - Lock 2	3	6	2	2	3	4.3	26, 28 27, 49
3. Lock 2 - Lock 3	2	6	2	3	2	5.1	36, 61
4. Lock 3 - Lock 4	2	4	2	1	2	5.3	39, 63
5. Lock 4 - Lock 5[2]	8	32	5	23	8	5.0	18, 54 19, 34 20,149
6. Lock 5 - Lock 6	2	4	2	1	2	3.9	17, 47
7. Lock 6 - Thompson Is. Dam	1	2	1	1	1	7.2[3]	8, 43
8. Thompson Is. Dam - Lock 7	3	6	2	2	3	4.8	12, 85

[1] For Location of Disposal Areas See Plates III and IV.
[2] Because of the amount of equipment required, these reaches would probably be divided into several subreaches and dredged over several seasons.
[3] This time required can be reduced by using 2 dredges for 3.6 months.

TABLE VI-8

UPPER HUDSON RIVER
COMPLETE REMOVAL
ALTERNATIVES 3 and 3A - CLAMSHELL EXCAVATION WITH
MECHANICAL UNLOADING TO SINGLE DISPOSAL SITE

Reach	Dredges	Scows	Rehandling Clamshells	Tugs Large	Tugs Small	Months Required	Disposal Areas[1]
1. Federal Dam - Lock 1[2]	4	24	3	19	4	4.5	Area Nos. 11 & 12, 108 Acres
2. Lock 1 - Lock 2[2]	3	18	2	14	3	4.3	Area Nos. 11 & 12, 77 Acres
3. Lock 2 - Lock 3	2	10	2	7	2	5.1	Area Nos. 11 & 12, 61 Acres
4. Lock 3 - Lock 4	2	10	2	7	2	5.3	Area Nos. 11 & 12, 63 Acres
5. Lock 4 - Lock 5[2]	8	32	5	23	8	5.0	Area Nos. 11 & 12, 237 Acres
6. Lock 5 - Lock 6	2	6	2	3	2	3.9	Area Nos. 11 & 12, 47 Acres
7. Lock 6 - Thompson Is.	1	2	1	1	1	7.2[3]	Area Nos. 11 & 12, 43 Acres
8. Thompson Is. - Lock 7	3	6	2	2	3	4.8	Area Nos. 11 & 12, 85 Acres

[1] For Location of Disposal Areas See Plates III and IV.
[2] Because of the equipment required, these reaches would probably be subdivided and dredged over several seasons.
[3] This time required can be reduced by using 2 dredges for 3.6 months.

TABLE VI-9

UPPER HUDSON RIVER
COMPLETE REMOVAL
COST COMPARISON WITH RETURN FLOW TREATMENT
BY COAGULATION AND SEDIMENTATION
COSTS IN MILLION $

Reach	Alternative 1 - Hydraulic Dredging, Multiple Disposal Sites	Alternative 2 - Clamshell Excavation-Mechanical Unloading, Multiple Disposal Sites	Alternative 3 - Clamshell Excavation-Mechanical Unloading, Single Disposal Site	Alternative 3A - Alternative 3 with Conveyor Transport
1. Federal Dam - Lock 1	26.2	24.0	29.5	26.6
2. Lock 1 - Lock 2	24.3	15.0	20.8	18.7
3. Lock 2 - Lock 3	17.5	13.5	15.5	13.8
4. Lock 3 - Lock 4	14.7	13.1	16.2	14.4
5. Lock 4 - Lock 5	86.1	55.4	54.3	47.7
6. Lock 5 - Lock 6	8.0	9.9	10.1	8.9
7. Lock 6 - Thompson Island Dam	8.6	10.5	10.5	11.8
8. Thompson Island Dam - Lock 7	16.1	16.9	16.2	13.8
TOTAL	201.5	158.3	173.1	155.7

NOTE: A least cost system could be assembled by combining elements of Alternatives 1 and 2. Cost for such a system would be $153.7 million.

TABLE VI - 10

UPPER HUDSON RIVER
COMPLETE REMOVAL
COST COMPARISON WITH RETURN FLOW TREATMENT
INCLUDING FILTRATION-ADSORPTION
COSTS IN MILLION $

Reach	Alternative 1 - Hydraulic Dredging, Multiple Disposal Sites	Alternative 2 - Clamshell Excavation-Mechanical Unloading, Multiple Disposal Sites	Alternative 3 - Clamshell Excavation-Mechanical Unloading, Single Disposal Site	Alternative 3A Alternative 3 with Conveyor Transport
1. Federal Dam - Lock 1	39.2	24.6	30.2	27.2
2. Lock 1 - Lock 2	34.7	15.6	21.5	19.3
3. Lock 2 - Lock 3	27.9	14.1	16.1	14.4
4. Lock 3 - Lock 4	25.1	13.8	16.8	15.0
5. Lock 4 - Lock 5	112.1	56.1	54.9	48.4
6. Lock 5 - Lock 6	18.4	10.6	10.8	9.5
7. Lock 6 - Thompson Island Dam	19.0	11.2	11.2	12.4
8. Thompson Island Dam - Lock 7	29.1	17.5	16.8	14.5
TOTAL	305.5	163.5	178.3	160.7

In Tables VI-6 through VI-10 dredging equipment and costs are grouped by pool. However, equipment availability and canal traffic limitations make it impractical to operate more than three to four dredges in the Upper Hudson at one time. If three dredges were used each dredging season, complete dredging of the Upper Hudson would take 8 years.

Costs in this report are current, 1978, costs. These costs will require recalculation, due to inflation, when the final scope and timing of a dredging program is decided.

Examination of Tables VI-9 and VI-10 indicates the following:

- If return flow treatment by filtration-adsorption is included then the clamshell excavation alternatives are much less expensive (from $127 to $145 million less) than hydraulic dredging.
- Even without including filtration-adsorption the clamshell alternatives are still less ($28 to $46 million) than hydraulic dredging.
- If clamshell excavation with mechanical unloading is selected, the additional cost of using a single disposal site is not large (approximately $15 million).
- The least expensive alternative is clamshell dredging using a conveyor to transport dredged material to the disposal area. However this alternative requires a large initial investment and therefore an early commitment to total removal.

Summary of Dredging System Cost/Performance

Tables VI-11 and VI-12 summarize performance/cost parameters for the four dredging systems, and two levels of return flow treatment, considered.

TABLE VI - 11

UPPER HUDSON RIVER
COMPLETE REMOVAL
DREDGING SYSTEMS PERFORMANCE/COST WITH
RETURN FLOW TREATMENT BY COAGULATION AND SEDIMENTATION

Dredging System	No. of Disposal Sites	PCB Recovery (lbs)	Recovery Ratio (%)	Cost (Million $)	Unit Cost ($/lb)
Alternative 1 - Hydraulic Dredging	17	357,900	91	201.5	560
Alternative 2 - Clamshell Excavation, Mechanical Unloading	11	367,200	94	158.3	430
Alternative 3 - Clamshell Excavation, Mechanical Unloading	1	367,200	94	173.1	470
Alternative 3A - Clamshell Excavation, Mechanical Unloading, Conveyor Transport	1	367,200	94	155.7	425

TABLE VI - 12

UPPER HUDSON RIVER
COMPLETE REMOVAL
DREDGING SYSTEMS PERFORMANCE/COST WITH RETURN FLOW TREATMENT INCLUDING FILTRATION - ADSORPTION

Dredging System	No. of Disposal Sites	PCB Recovery (lbs)	Recovery Ratio (%)	Cost (Million $)	Unit Cost ($/lb)
Alternative 1 - Hydraulic Dredging	17	381,700	97	305.5	800
Alternative 2 - Clamshell Excavation, Mechanical Unloading	11	368,850	94	163.5	445
Alternative 3 - Clamshell Excavation, Mechanical Unloading	1	368,850	94	178.3	485
Alternative 3A - Clamshell Excavation, Mechanical Unloading, Conveyor Transport	1	368,850	94	160.7	435

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CHAPTER VI

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CHAPTER VII

ALTERNATIVE SYSTEMS FOR PARTIAL PCB REMOVAL

Introduction

This chapter will consider the removal of PCB contaminated bed materials in a quantity less than the total amount contained in the Upper Hudson. Although there are probably an infinite number of strategies for partial removal, this chapter will confine itself to the examination of one such strategy, that is, removal of deposits with a PCB concentration greater than 50 µg per g. This action level was established by DEC staff and may require revision as a more complete understanding of the impact of PCB on aquatic life and water quality is developed.

This chapter is subdivided into three sections:

- PCB Removal and Dredging Quantities
- Dredging Systems
- Dredging Systems Cost/Performance

As discussed in Chapter II, areas containing PCB concentrations greater than 50 µg per g in a surface grab or core sample segment were plotted for the Lock 5, Lock 6 and Thompson Island Pools. Such areas are called "hot spots."

Lack of data did not permit the delineation of hot spots for remaining five pools of the Upper Hudson. These five represent 29.5 mi, or 74 percent, of the total 39.8 mi length of the Upper Hudson.

PCB Removal and Dredging Quantities

PCB quantities and contaminated volumes were calculated from the base maps discussed in Chapter II, and are based on the following assumptions:

- Bed material coverage 80 percent.
- Depth of contamination in Lock 5 and 6 Pools 15 in., in Thompson Island Pool 24 in.
- The PCB quantity in each hot spot area is determined by using the unweighted average of the surface grab samples and the weighted average of the core samples. The average concentration of all hot spot areas within a pool is determined by dividing the total PCB quantity of the hot spots by the total contaminated volume of the hot spots.
- Bed material density used is 65 lbs per cu ft.

Table VII-1 tabulates PCB concentrations and quantities for the hot spot areas of the Lock 5, Lock 6 and Thompson Island Pools. As shown, areas with a PCB contamination greater than 50 µg per g in these three pools contain a total of 148,200 lbs of PCB. This is 82 percent of the PCB quantity in these three pools, or 38 percent of the total in the Upper Hudson.

Table VII-2 tabulates contaminated and removal volumes for the Lock 5, Lock 6 and Thomspon Island Pools.

TABLE VII-1

UPPER HUDSON RIVER
PCB QUANTITIES IN AREAS WITH
CONTAMINATION ≥ 50 μG PER G

	Full River		Areas with PCB Concentration ≥ 50 μg/g		
Reach[1]	Avg. PCB Concentration (μg/g)	PCB Quantity (1000 lbs)	Avg. PCB Concentration (μg/g)	PCB Quantity (1000 lbs)	Percent of PCB in "Hot Spots" (%)
1. Federal Dam - Lock 1	20	31.6			
2. Lock 1 - Lock 2	25	28.1			
3. Lock 2 - Lock 3	50	44.8			
4. Lock 3 - Lock 4	40	37.2			
5. Lock 4 - Lock 5	20	69.8			
6. Lock 5 - Lock 6	65	44.5	110	40.5	91
7. Lock 6 - Thompson Island Dam	55	34.7	60	33.0	95
8. Thompson Island Dam - Lock 7	50	100.9	125	74.7	74
Total	35	391.6	100	148.2	38

TABLE VII-2

UPPER HUDSON RIVER
CONTAMINATED AND REMOVAL VOLUMES IN
AREAS WITH PCB CONTAMINATION ≥ 50 μG PER G

Reach	Full River: Contaminated Volume[1] (10^6 cu yd)	Full River: Removal Volume[2] (10^6 cu yd)	Areas with PCB Contamination ≥ 50 μg/g: Contaminated Volume[1] (10^6 cu yd)	Areas with PCB Contamination ≥ 50 μg/g: Removal Volume (10^6 cu yd)	Areas with PCB Contamination ≥ 50 μg/g: Ratio of "Hot Spot" Removal Volume to Total (%)
1. Federal Dam - Lock 1	0.90	2.18			
2. Lock 1 - Lock 2	0.64	1.54			
3. Lock 2 - Lock 3	0.51	1.20			
4. Lock 3 - Lock 4	0.53	1.28			
5. Lock 4 - Lock 5	1.99	4.77			
6. Lock 5 - Lock 6	0.39	0.94	0.21	0.49	52
7. Lock 6 - Thompson Island Dam	0.36	0.86	0.29	0.69	80
8. Thompson Island Dam - Lock 7	1.15	1.72	0.33	0.50	29
Total	6.47	14.51	0.83	1.68	12

[1] Based on 24 in. depth of contamination in Thompson Island Pool, and 15 in. elsewhere.
[2] Based on 36 in. removal.

Examination of these tables indicates the inherent efficiencies of dredging limited areas with higher PCB concentrations: the average concentration of the contaminated material removed is increased from 55 μg per g with complete removal to 100 μg per g for "hot spot" dredging.

Dredging Systems

In Chapter VI, various dredging systems were considered for complete removal of PCB contaminated river bed materials. The clamshell dredging alternatives were found to be the most cost-effective.

In this chapter, dredging costs for partial removal will be computed using Alternative 3, clamshell dredging, with mechanical unloading and truck transport to a single disposal site.

The conveyor transport option, Alternative 3A, was not considered at this time, because the volume removed from hot spots in the Lock 5, Lock 6 and Thompson Island Pools is insufficient to justify the capital investment required by a conveyor system. When additional data is available, and the extent of dredging in the remaining five pools defined, reexamination of the conveyor option may be advantageous.

Table VII-3 presents pertinent details for each of the three reaches, for the dredging system considered. Cost

TABLE VII-3

UPPER HUDSON RIVER
PARTIAL REMOVAL
CLAMMSHELL EXCAVATION WITH
MECHANICAL UNLOADING TO SINGLE DISPOSAL SITE

Reach	Dredges	Scows	Rehandling Clamshells	Tugs Large	Tugs Small	Months Required	Disposal Areas[1]
1. Federal Dam - Lock 1							
2. Lock 1 - Lock 2							
3. Lock 2 - Lock 3							
4. Lock 3 - Lock 4							
5. Lock 4 - Lock 5							
6. Lock 5 - Lock 6	1	3	1	1	1	4.1	Areas 11 & 12, 24 Acres
7. Lock 6 - Thompson Is.	1	2	1	1	1	5.8	Areas 11 & 12, 34 Acres
8. Thompson Is. - Lock 7	1	2	1	1	1	4.2	Areas 11 & 12, 25 Acres

[1] For Location of Disposal Areas See Plates III and IV.

estimates for partial dredging were prepared and are presented in Appendix G.

Dredging System Cost/Performance

Table VII-4 summarizes the cost and performance for a clamshell excavation system, with mechanical unloading, to a single disposal site, dredging only areas with contamination above 50 μg per g, in the Lock 5, Lock 6 and Thompson Island Pools.

Total PCB recovery from these three pools is estimated at 139,000 lbs, considering both dredgehead and return flow losses, and PCB intentionally not dredged because it is in an area below 50 μg per g. This PCB recovery quantity represents 36 percent of the total estimated in the Upper Hudson; 77 percent of the total in the three pools considered.

A total area of approximately 85 acres would be required for the disposal of material dredged from these three pools. Since individual suitable disposal sites several times larger than this exist in the Upper Hudson vicinity, it may be prudent to acquire a site larger than required to allow for dredging in the remaining pools, or for the disposal of PCB contaminated materials from areas outside the study area. Additional costs for sites larger than 85 acres

TABLE VII-4

UPPER HUDSON RIVER
PARTIAL REMOVAL
CLAMSHELL EXCAVATION WITH MECHANICAL UNLOADING
TO SINGLE DISPOSAL AREA
RETURN FLOW TREATMENT BY COAGULATION AND SEDIMENTATION
SYSTEM COST/PERFORMANCE

Reach	PCB Recovery (lbs)	Recovery Ratio (%)	Cost (Million $)	Unit Cost ($/lb)
1. Federal Dam - Lock 1				
2. Lock 1 - Lock 2				
3. Lock 2 - Lock 3				
4. Lock 3 - Lock 4				
5. Lock 4 - Lock 5				
6. Lock 5 - Lock 6	38,000	85	5.9	155
7. Lock 6 - Thompson Island Dam	30,800	89	9.2	300
8. Thompson Island Dam - Lock 7	70,200	70	5.9	85
Total	139,000	36	21.0	150

have not been included in the partial dredging estimates discussed below.

Dredging costs are also tabulated in Table VII-4. These costs are in 1978 dollars and are computed based on the same major assumptions discussed in Chapter VI. The total cost for partial dredging of the three pools considered is $21,000,000. In comparison, total dredging of the entire Upper Hudson, using the same dredging system, was estimated to cost $173,100,000, and would recover 367,200 lbs of PCB (see Table VI-11). Thus partial dredging in three pools would recover 38 percent of the PCB quantity as complete dredging, for approximately 12 percent of the cost.

Table VII-4 also tabulates unit PCB recovery costs. Costs range from $85 to $300 per lb of PCB recovered; average for the three pools is $150 per lb, compared with an average for complete dredging, using the same dredging system, of $470 per lb PCB recovered.

CHAPTER VIII

FINDINGS, CONCLUSIONS AND RECOMMENDATIONS

Introduction

This chapter summarizes the findings and conclusions contained in this volume of the Feasibility Report, and presents recommendations drawn from these conclusions.

In organization, this chapter follows the body of the report, with the following divisions:

- Existing Conditions
- Dredging Technology
- Disposal Sites
- Return Flow Treatment
- Alternative Systems for Total PCB Removal
- Alternative Systems for Partial PCB Removal
- Recommendations
- Implementation

Existing Conditions

An extensive river bed material and PCB sampling program has been carried out over the Upper Hudson. A total of 641 samples were collected over the 39.8 mile length of the Upper Hudson, an average of 16 samples per mile. Most of the samples were collected in the three upper pools, between

Lock 5 (RM 183.4) and Ft. Edward (RM 193.7). In this 10.3 mile segment of the river, 493 samples were collected for an average of 48 per mile.

In the 29.5 mile remainder of the Upper Hudson 148 samples were collected for an average of 5 per mile.

Based on this data, an average PCB concentration of 35 μg per g was calculated for the entire Upper Hudson. Individual pool concentrations were found to range from 20 μg per g in the Federal Dam Pool to 65 μg per g in the Lock 5 pool.

Based on bed material coverage of 80 percent, and depths of contamination of 24 in. in the Thompson Island Pool and 15 in. elsewhere, the total PCB quantity in the Upper Hudson River is estimated to be 391,600 lbs.

Additional PCB depth and distribution data would enable refinement of PCB quantities, but would not affect dredging quantities or costs, since 36 in. removal (24 in. minimum cut plus 12 in. overcut) appears to be the practical dredging limit with currently available equipment.

Dredging Technology

The most feasible dredging methods for complete removal of PCB-contaminated bed material from the Upper Hudson, or for a large scale partial removal program, are hydraulic cutterhead dredges with pipeline transport to multiple disposal sites, or clamshell dredges with barge transport to either single or multiple sites.

Advanced dredging technology, typified by current Japanese pollution-abatement dredging (Oozer, Clean-up, etc.), was not found to be currently available in the U.S. In addition, this equipment was developed for dredging high water content mucks ("hedoro") and would probably not be effective for the Upper Hudson, because the bed material is coarse and debris-laden. Furthermore, the advantages of these dredge types in reduced dredge-head turbidity do not appear to be significant in improving overall PCB recoveries, for bed materials typical of the Upper Hudson.

If it should be decided to implement a limited partial dredging program, the question of dredging equipment could be reopened, since certain equipment may be suitable for such a reduced program, but not for the large scale effort considered in this report.

Disposal Sites

Based on New York State criteria for secure land burial facilities, forty suitable dredged material disposal sites were located within the Study Area. These sites had a total area of approximately 3,200 acres. Most of the sites (about 90 percent of the total area) were north of Lock 4.

Return Flow Treatment

Both hydraulic and clamshell dredging operations result in an effluent which must be returned to the river, and which contains PCB and other contaminants present in the dredged material. The volume of return flow produced by hydraulic dredging is many times larger than that produced by clamshell.

Feasible treatment methods include sedimentation, sedimentation plus coagulant addition, and filtration-adsorption.

Estimated PCB effluent concentrations for these treatment methods are:

	Effluent PCB Concentration (µg/l)
Sedimentation	50-150
Sedimentation plus Coagulation	25-100
Filtration-Adsorption	1-2

These effluent concentrations are based on in situ river bed material PCB concentrations in the range of 50 to 150 µg per g.

Previously applied standards for return flow PCB concentrations have limited such concentrations to a maximum of 10 µg per l. Although such standards may not be applied to this project, the only treatment method which can be relied upon to meet them is filtration-adsorption.

Alternative Systems for Complete PCB Removal

The complete removal option contemplates bank-to-bank dredging of the entire 39.8 mile length of the Upper Hudson, to a depth of 36 in. Based on an estimated river bed material coverage of 80 percent, the quantity of dredged material would be approximately 14.5 million cu yds.

Four alternatives for complete removal were investigated:

1. Hydraulic cutterhead dredges with pipeline transport to multiple disposal sites.
2. Clamshell dredges with barge/truck transport to multiple disposal sites.
3. Clamshell dredges with barge/truck transport to a single disposal site.

3A. Clamshell dredges with barge/conveyor transport to a single disposal site.

Alternative 3 would cost approximately $173,000,000 recover 94 percent of the PCB and have a unit cost of $470 per lb of PCB recovered.

Alternative 3A was found to be the most cost-effective, with a total 1978 cost of approximately $156,000,000, a PCB recovery ratio of 94 percent, and a unit cost of $425 per lb of PCB recovered. This latter alternative may not be feasible because of the required commitment to full dredging of the upper Hudson.

Alternative Systems for Partial PCB Removal

For the three northernmost pools of the Upper Hudson (Lock 5, Lock 6 and Thompson Island) sufficient data was available to delineate "hot spots," which are defined as areas with a PCB concentration equal to or greater than 50 μg per g.

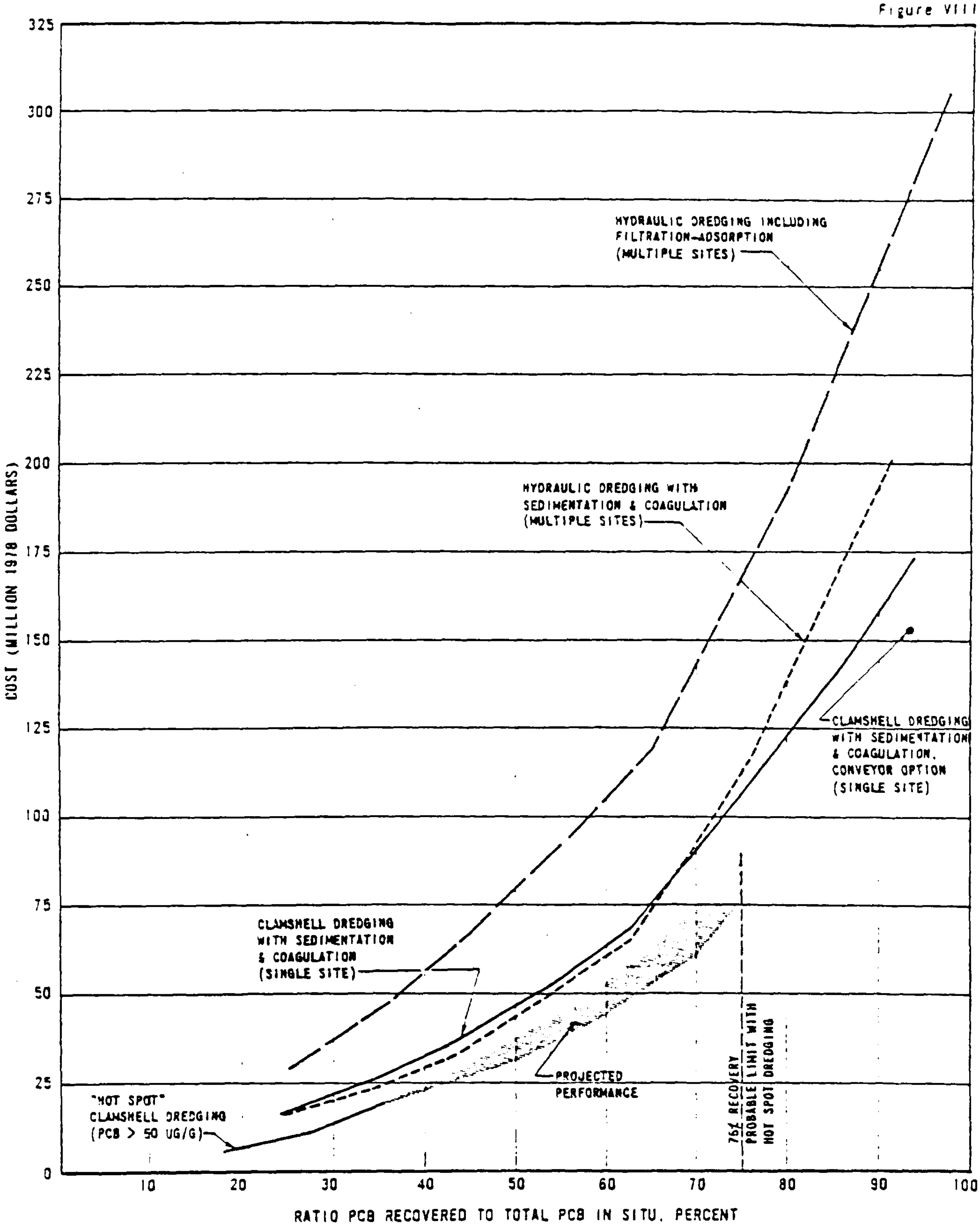
It is estimated that "hot spots" in these three pools contain about 148,000 lbs of PCB, or 38 percent of the total in the Upper Hudson. The contaminated volume in these three pools is 830,000 cu yd, or 13 percent of the total.

Clamshell dredging, with barge and truck transport to a single disposal site, was evaluated for "hot spot" dredging. Cost, for the three pools considered, was $21,000,000 (1978 $); PCB recovery 36 percent of the Upper Hudson total; and unit cost $150 per lb of PCB recovered.

Cost/Performance

Figure VIII-1 illustrates cost-performance relationships for both complete and partial dredging, using clamshell and hydraulic systems. Hydraulic systems are shown both with and without filtration-adsorption for return flow treatment; clamshell systems with sedimentation plus coagulation only.

The curves shown for each alternative are drawn by plotting the cost-recovery ratio function for each pool, in



DREDGING COST/PERFORMANCE

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order of decreasing cost-effectiveness. The curves therefore represent approximate optimization curves for each alternative.

From these curves the following conclusions can be drawn:

- Hydraulic dredging with filtration-adsorption is considerably more expensive than any other alternative at any level of PCB recovery.
- The highest PCB recovery ratio (97 percent) is achieved with hydraulic dredging with filtration-adsorption. Other systems can reach 91 to 94 percent.
- The three other complete dredging aternatives (hydraulic with sedimentation plus coagulation, and clamshell to single or multiple sites) are quite close in cost up to approximately 70% PCB recovery. Going beyond this point requires dredging in the least cost-effective (southernmost) pools, where hydraulic dredging is at the greatest disadvantage due to lack of disposal sites.
- Partial dredging is only plotted for the three pools for which sufficient data is available to delineate "hot spots."

At levels up to 36 percent PCB recovery, which is the limit of recovery from "hot spot" dredging in the three pools considered, partial dredging is more cost-effective than any other alternative.

Recommendations

This report is only one part of a comprehensive program initiated by the DEC to study all aspects of the PCB problem. The report is limited in scope to the study of dredging as a remedial program for the Upper Hudson River. It is not appropriate, therefore, to make recommendations on the utility of dredging, or to recommend the scope of a partial dredging program.

If, on the basis of this and other reports, it is decided to implement a program of complete PCB removal, the recommended method is clamshell excavation, with mechanical unloading and truck transport to a single unloading site ($173,100,000). A conveyor transport system would be somewhat less expensive ($155,700,000) but would require an immediate commitment to complete dredging with current technology, and is therefore not recommended. Use of multiple disposal sites would also be less expensive ($158,300,000), but would complicate site acquisition and long-term site monitoring programs.

If a "hot spot" dredging program is decided upon, the recommended method, for the Lock 5, Lock 6 and Thompson Island Pools, is clamshell excavation with truck transport to a single disposal site, at a cost of $21,000,000. For the remainder of the Upper Hudson, it is recommended that additional data on PCB distribution be obtained before a decision on a dredging system is made. If deposits are found to be limited in extent, small scale dredging equipment, such as the Amphidredge, may be suitable.

It should be noted that all costs in this report have been calculated in 1978 dollars. When the actual scope and implementation schedule of the remedial program is decided upon these costs will require adjustment to reflect expected price inflation.

The disposal site or sites developed during a dredging program will require maintenance, repair and environmental monitoring for an indefinite period. The annual cost of these activities have not been developed in detail but will vary from $50,000 to on the order of $150,000 per year depending upon the scope of the dredging program implemented.

Implementation

Since the scope of the dredging program has not been decided upon at this time, it is only possible to suggest the outline of an implementation plan. Table VIII-1 lists the main elements of such a plan, which are discussed below:

1.0 An implementation framework must be established by the State. This involves deciding if the PCB dredging program is to be carried out as a joint DEC/DOT program; as part of regular DOT maintenance dredging; by a separate, new, toxic materials control agency; or in some other way. Establish full time state project staff.

2.0 Detailed studies must be conducted to finalize dredging/transport systems and disposal site(s) location, and to select implementation and financ-

TABLE VIII-1

UPPER HUDSON RIVER
DREDGING OF PCB-CONTAMINATED BED MATERIALS
ELEMENTS OF IMPLEMENTATION PLAN

1.0 Establish Implementation Framework

2.0 Detailed Studies

- 2.1 Finalize Selection of Dredging/Transport System
- 2.2 Finalize Site Selection
  - 2.2.1 Subsurface Investigations
  - 2.2.2 Hydrogeologic Investigations
  - 2.2.3 Aerial Mapping
- 2.3 River Bed Probing Program
- 2.4 Finalize Implementation, Financing and Dredging Management Procedures.
- 2.5 Prepare Final Engineering Report (summarizes results of 2.0 through 2.4)
- 2.6 Prepare Environmental Impact (SEQR) Statement
- 2.7 Submit Corps of Engineers Permit Application and Request EPA Approval of Disposal Site

3.0 Site Acquisition

4.0 Final Design

- 4.1 Dredging/Transport System
- 4.2 Unloading Site
- 4.3 Disposal Site
- 4.4 Return Flow Treatment System

5.0 Contract Award Procedures

6.0 Dredging

7.0 DEC Monitoring

8.0 Long Term Maintenance and Monitoring

ing modes. Alternative dredging management programs (e.g. unit price bidding, equipment and crew leasing, equipment purchase) must be evaluated, and the best overall approach identified. The results of such investigations should be presented for approval as a Final Engineering Report. In addition, an Environmental Impact Statement should be prepared to meet SEQR and Corps of Engineers permit requirements, and EPA approval of hazardous material disposal site(s).

3.0 Disposal and unloading site(s) must be acquired, as well as rights of way for haul roads and/or pipelines.

4.0 Final design for the dredging/transport system, the unloading and disposal sites, and the return flow treatment system must be prepared.

5.0 State contracting procedures must be complied with, assuming the dredging work is to be done by contract and not by DOT personnel.

6.0 The dredging program involves mobilization, site preparation; treatment plant, unloading site, disposal site, and haul road construction; dredging, demobilization and site containment.

7.0 DEC monitoring during the dredging program, to ensure compliance with environmental criteria, is recommended.

8.0 Long-term maintenance and monitoring to insure integrity of disposal site.

In Figure VIII-2 a schedule for dredging implementation is presented. This schedule shows that the earliest dredging could begin would be the summer of 1979; and that, in order for this to occur, implementation should begin no later than April 1, 1978.

DREDGING OF PCB-CONTAMINATED BED MATERIALS
IMPLEMENTATION SCHEDULE

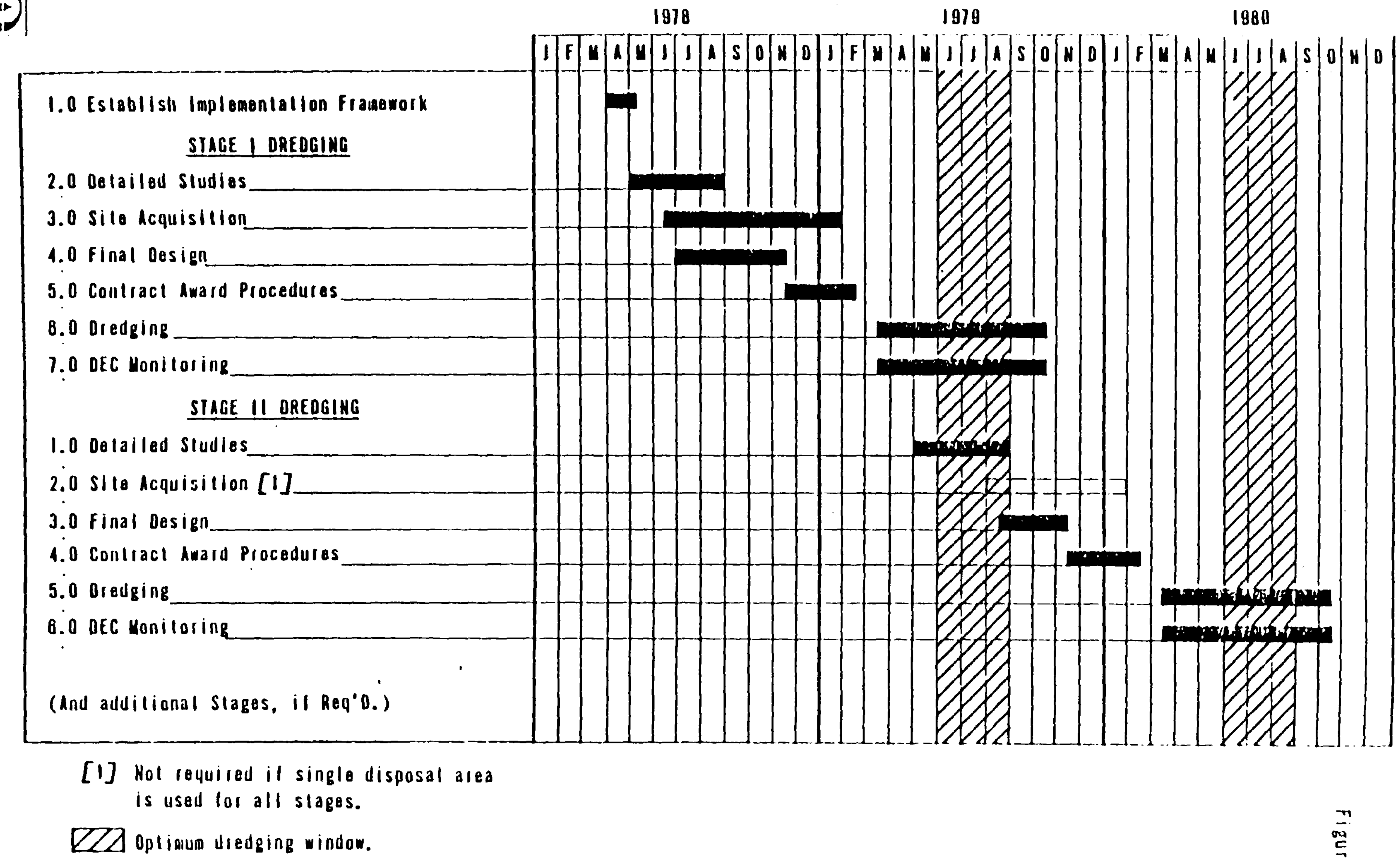

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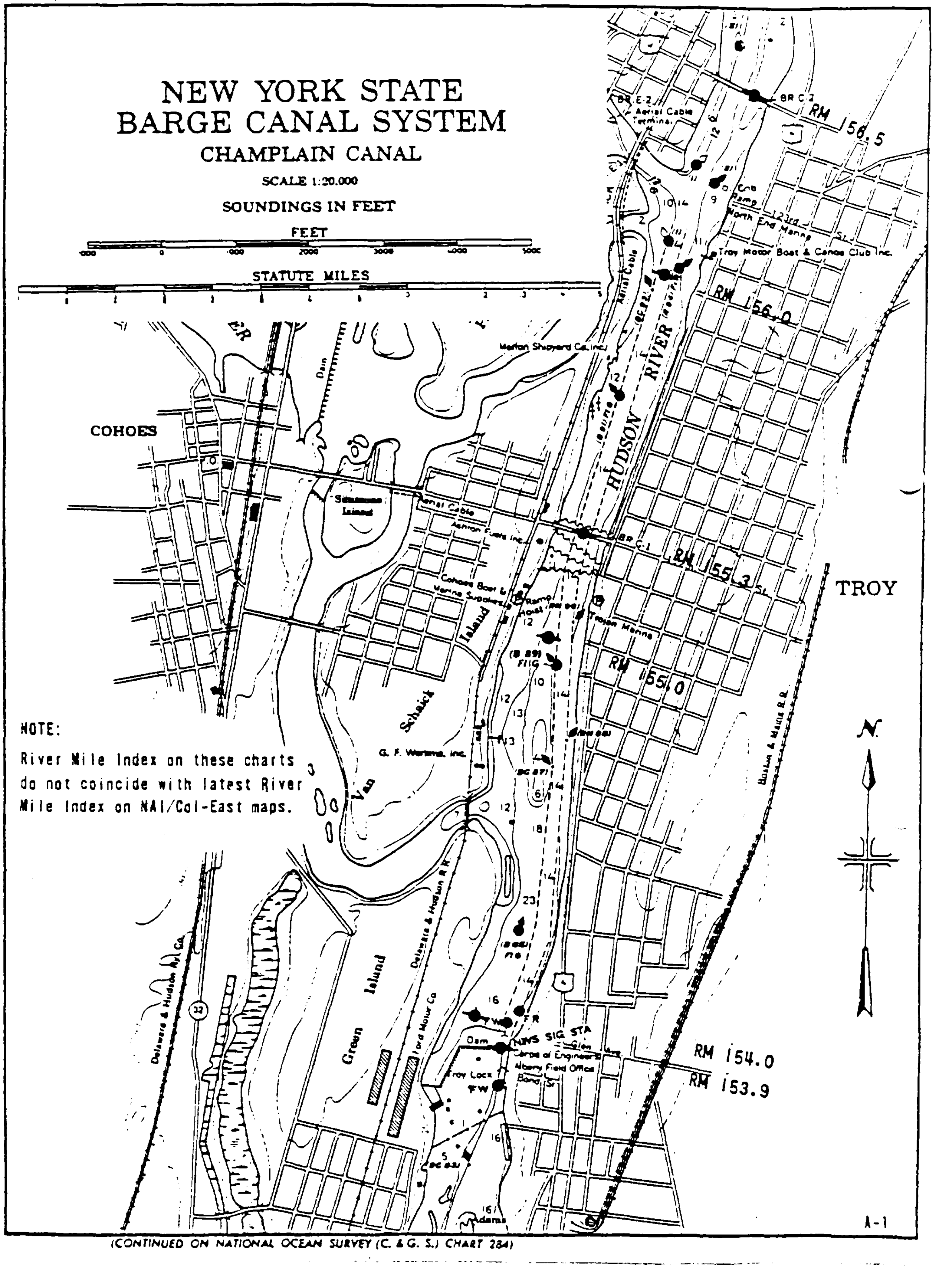
Figure VIII-2

APPENDIX A

NAVIGATIONAL CHARTS
CHAMPLAIN CANAL FROM TROY, NEW YORK
TO FORT EDWARD, NEW YORK

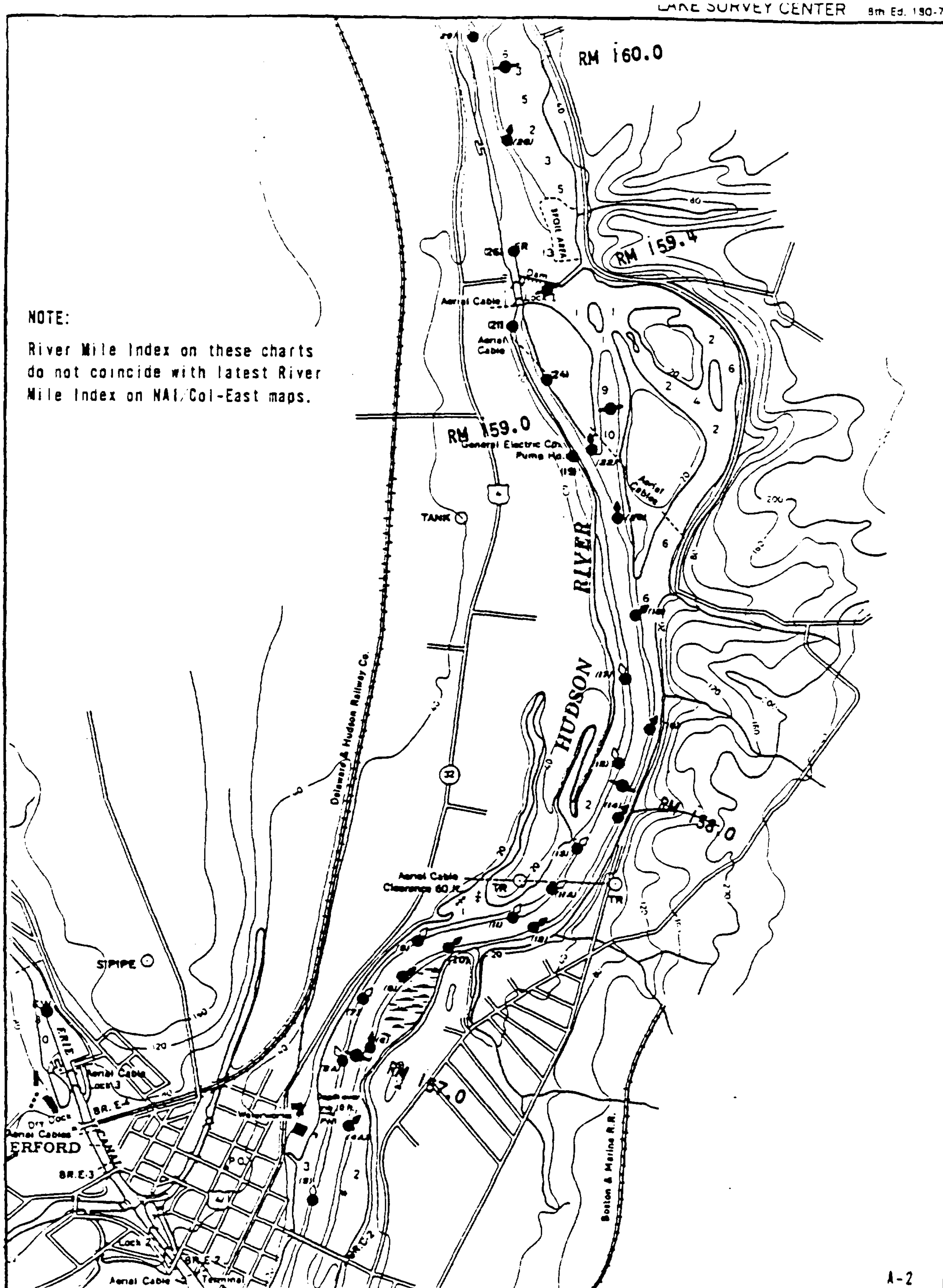
Source: Chart No. 180,
New York State Barge
Canal System, Lake
Survey Center, NOAA

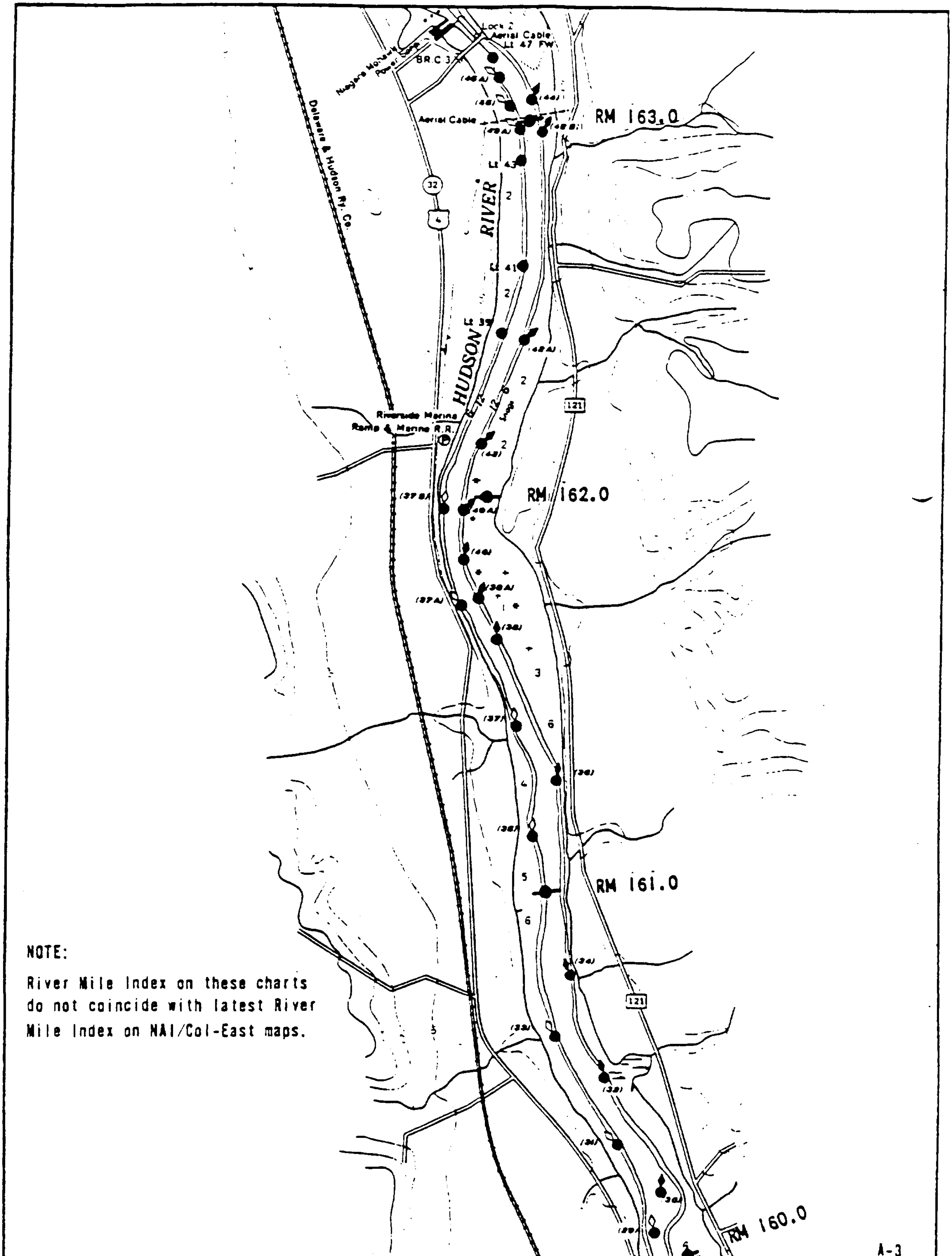


(CONTINUED ON NATIONAL OCEAN SURVEY (C. & G. S.) CHART 284)

NOTE:

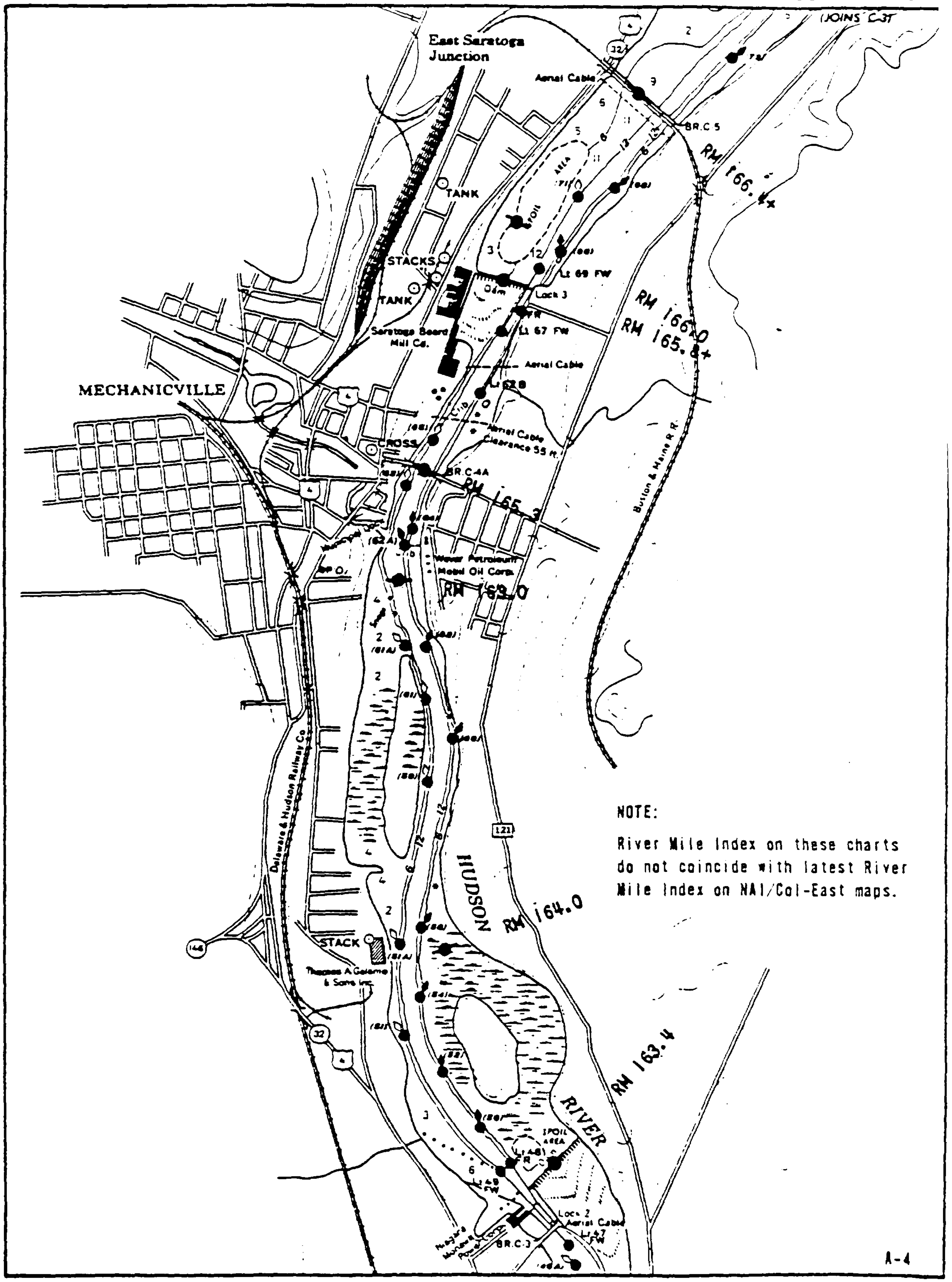
River Mile Index on these charts do not coincide with latest River Mile Index on NAI/Col-East maps.





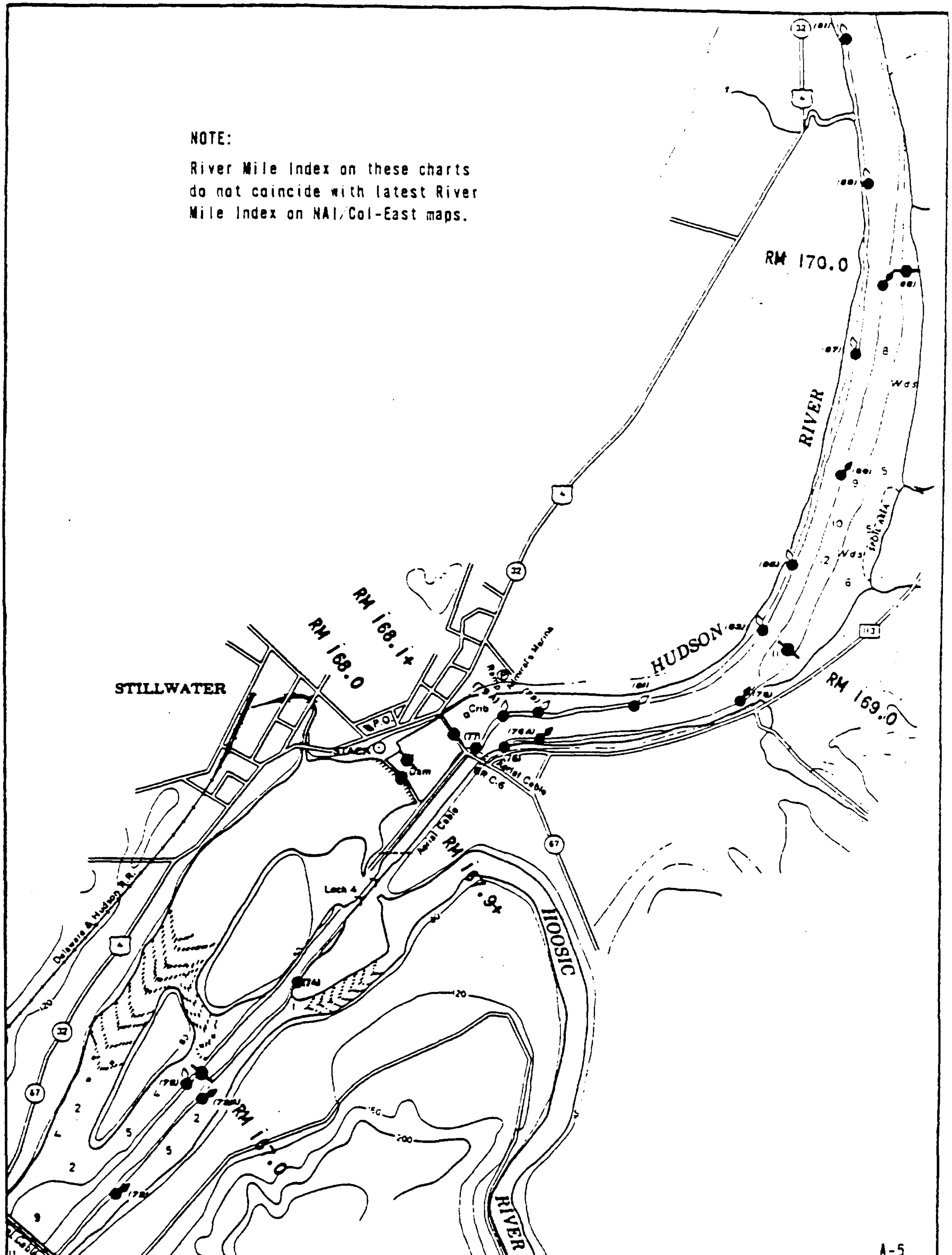
NOTE:

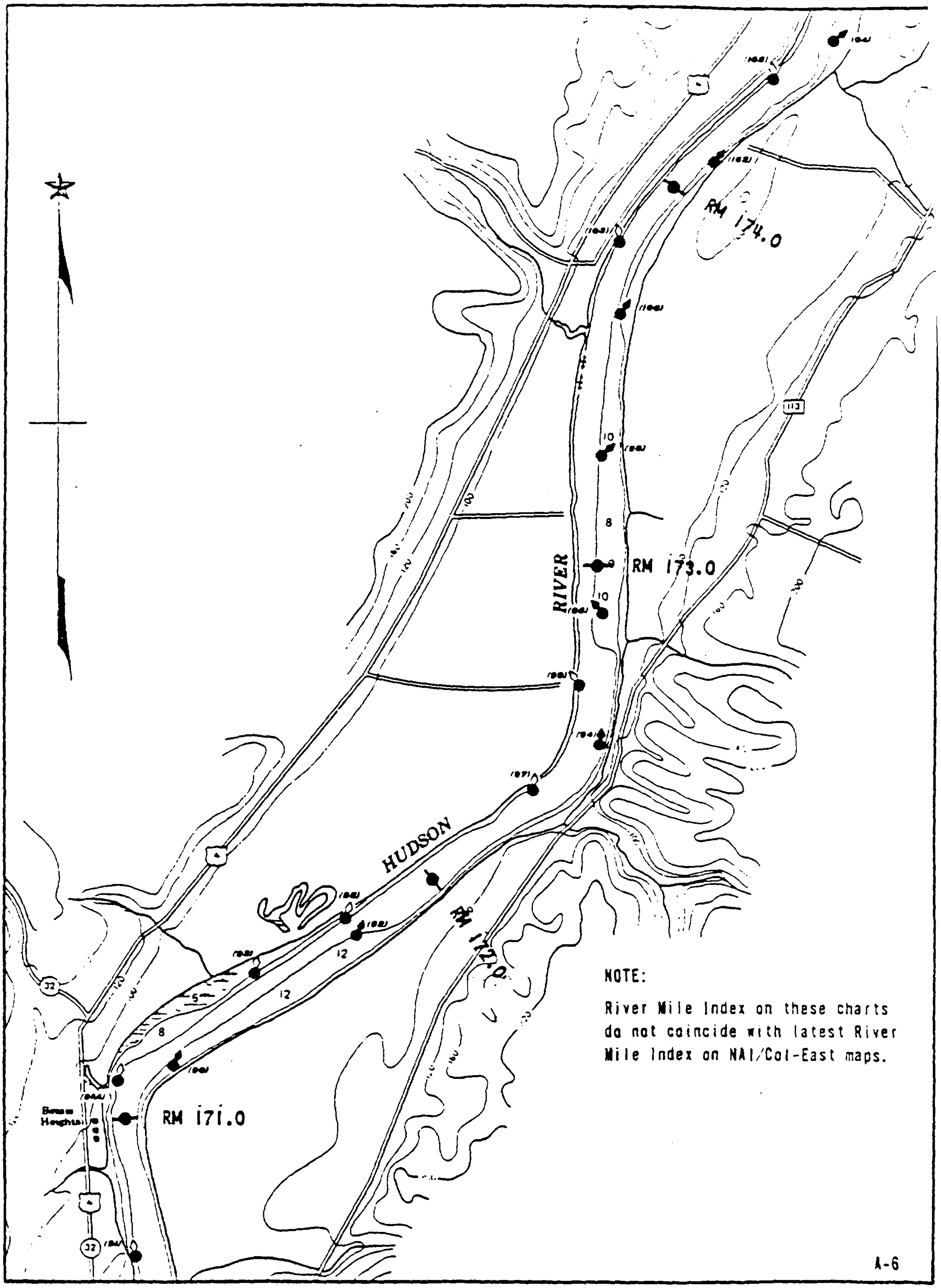
River Mile Index on these charts do not coincide with latest River Mile Index on NAI/Col-East maps.



NOTE:

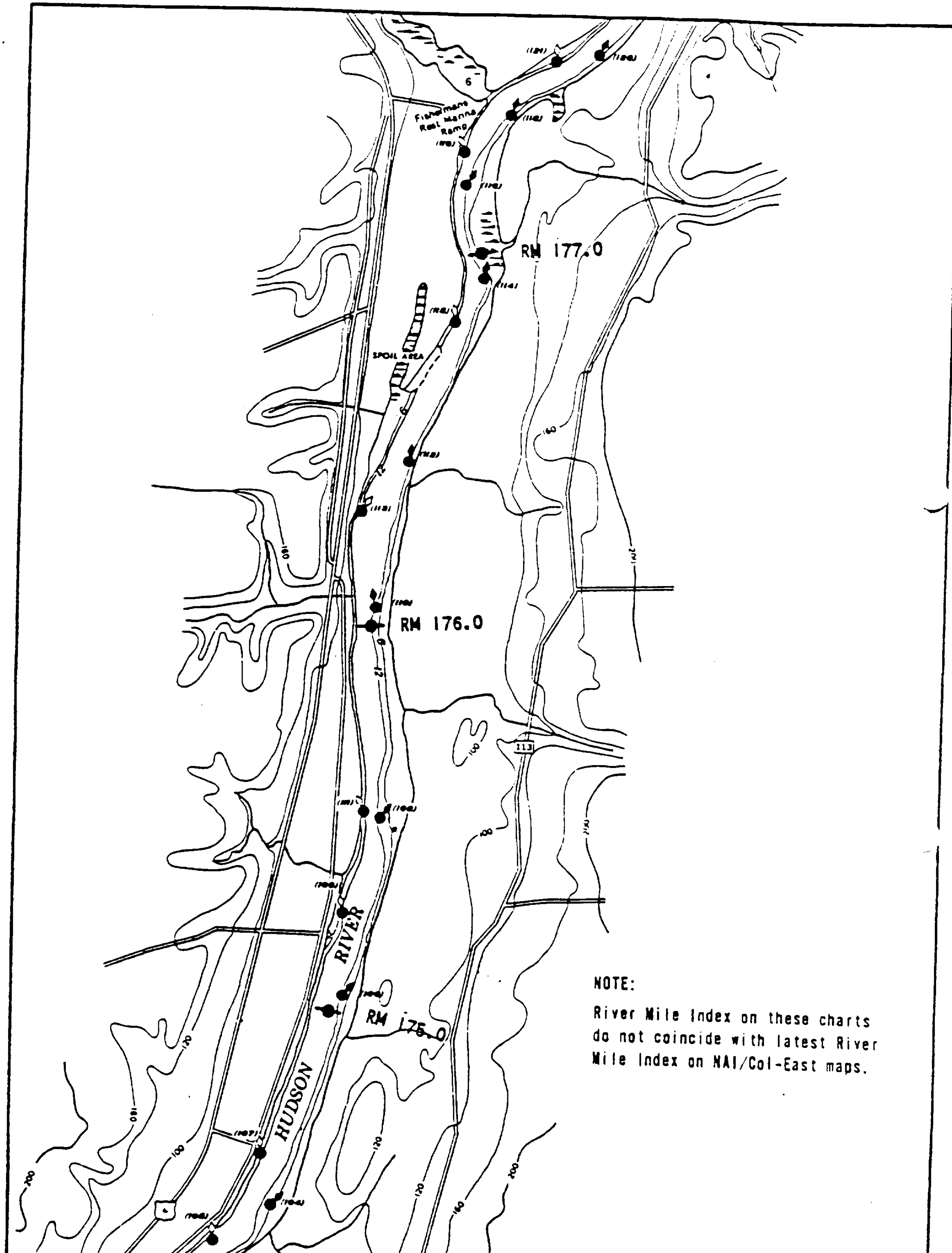
River Mile Index on these charts do not coincide with latest River Mile Index on NAI/Col-East maps.


NOTE:
River Mile Index on these charts do not coincide with latest River Mile Index on NAI/Col-East maps.
RM 170.0
RM 169.0
RM 168.1+
RM 168.0
RM 167.9+
RM 167.0
STILLWATER
HUDSON
RIVER
HOOSIC
RIVER
Delaware & Hudson R.R.
Lock 4
Dam
Aerial Cable
Crib
P.O.
STACK
Wds
Spoil Area



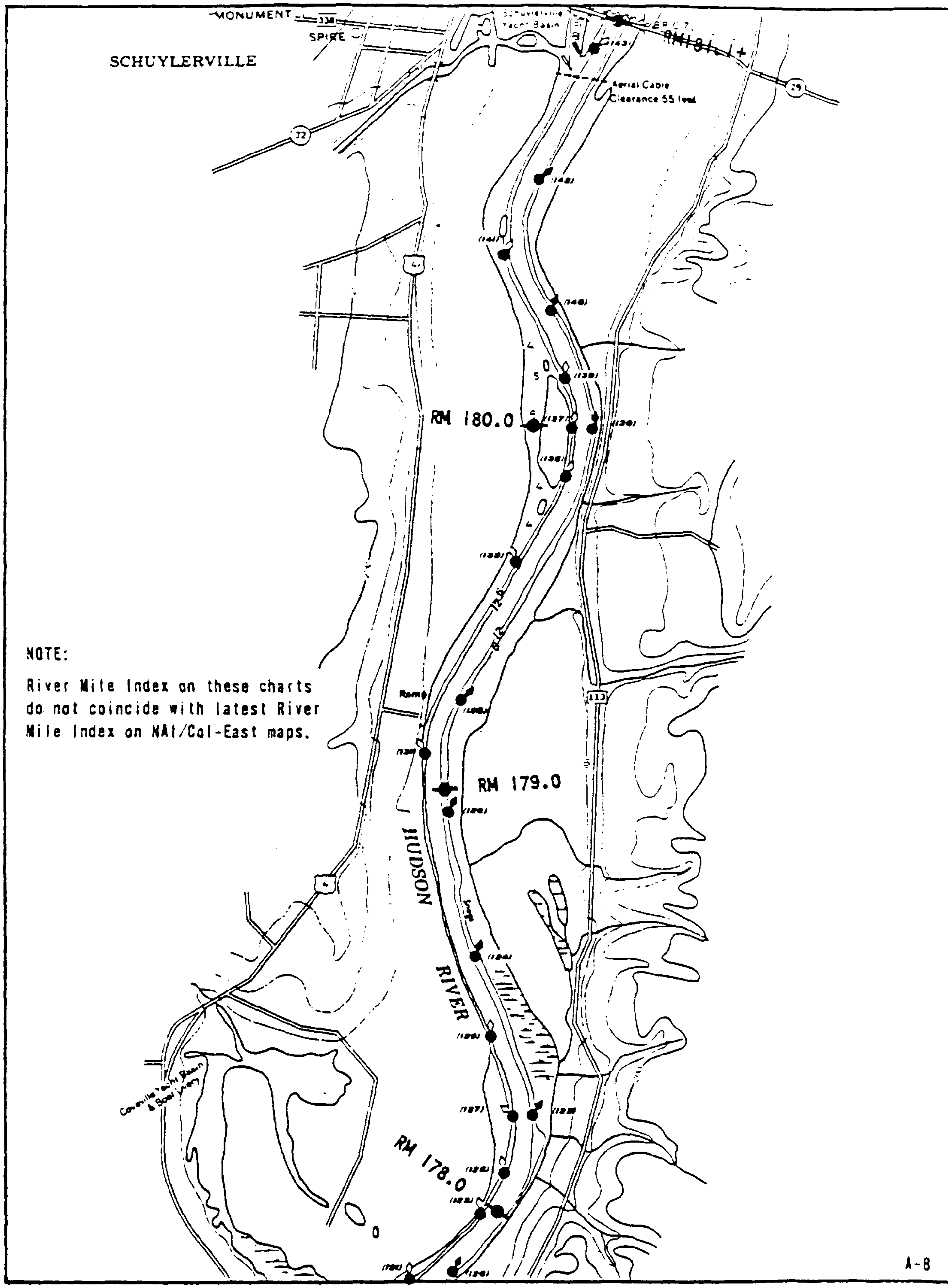
NOTE:

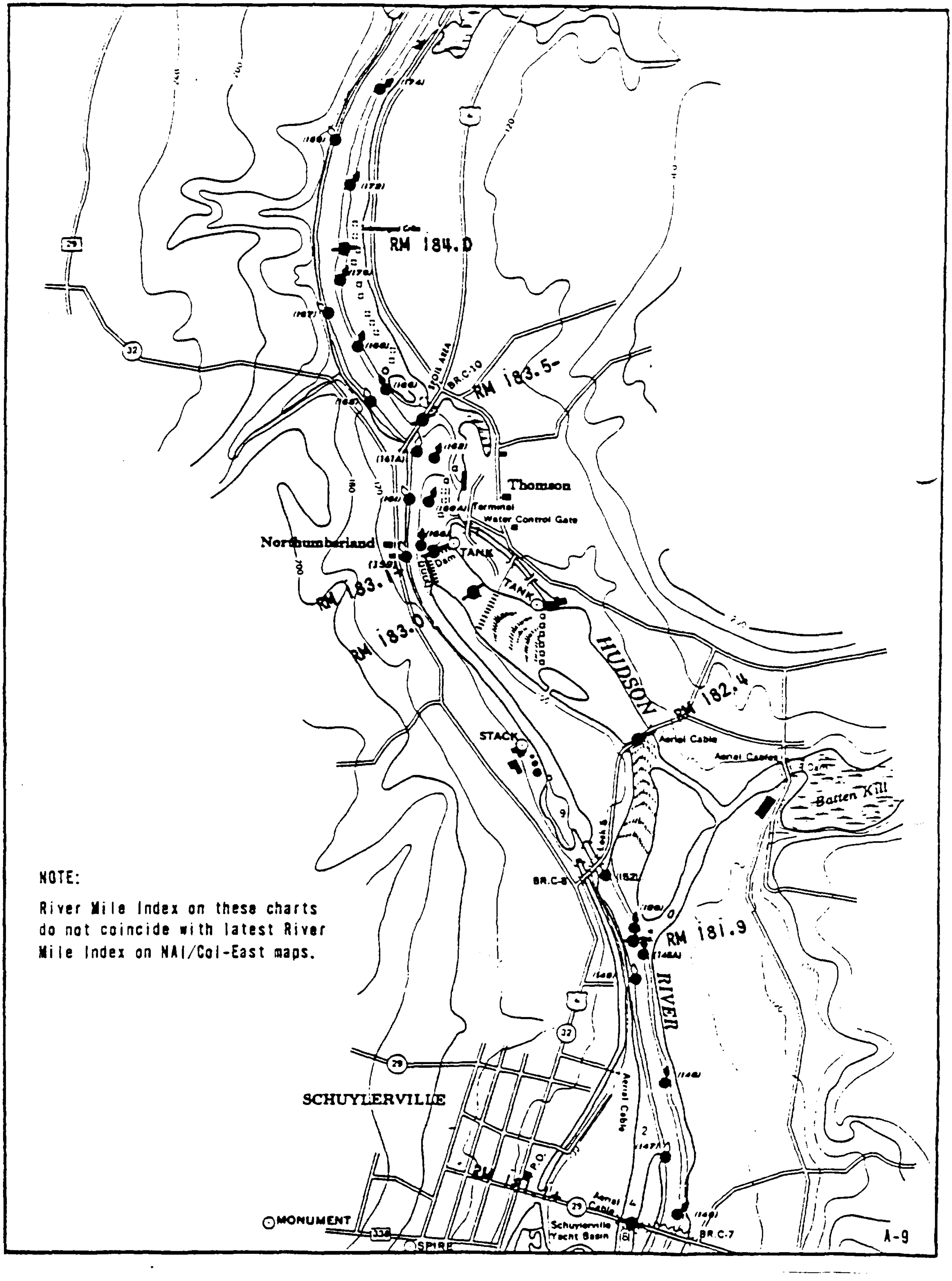
River Mile Index on these charts do not coincide with latest River Mile Index on NAI/Col-East maps.



NOTE:

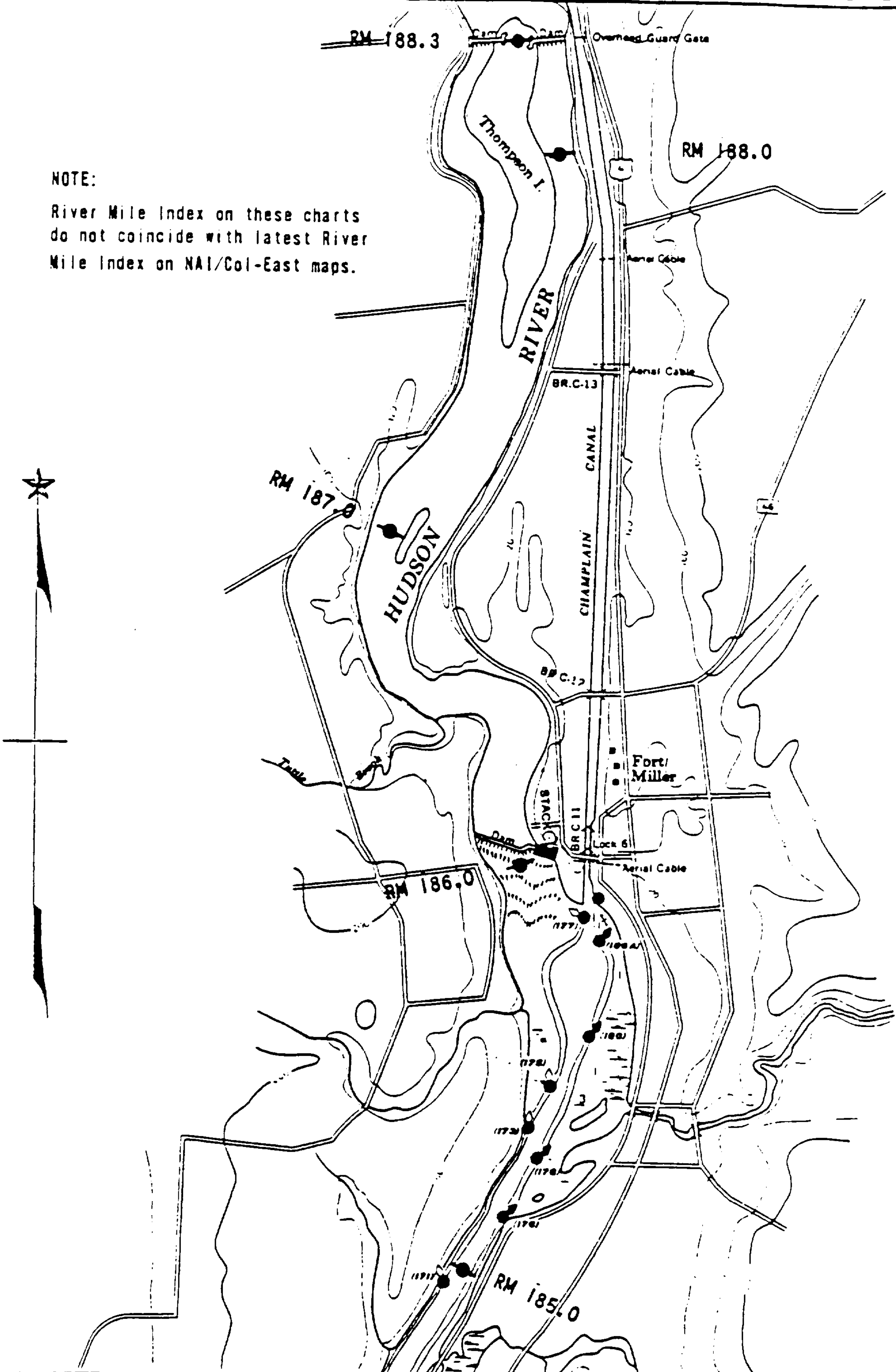
River Mile Index on these charts do not coincide with latest River Mile Index on NAI/Col-East maps.

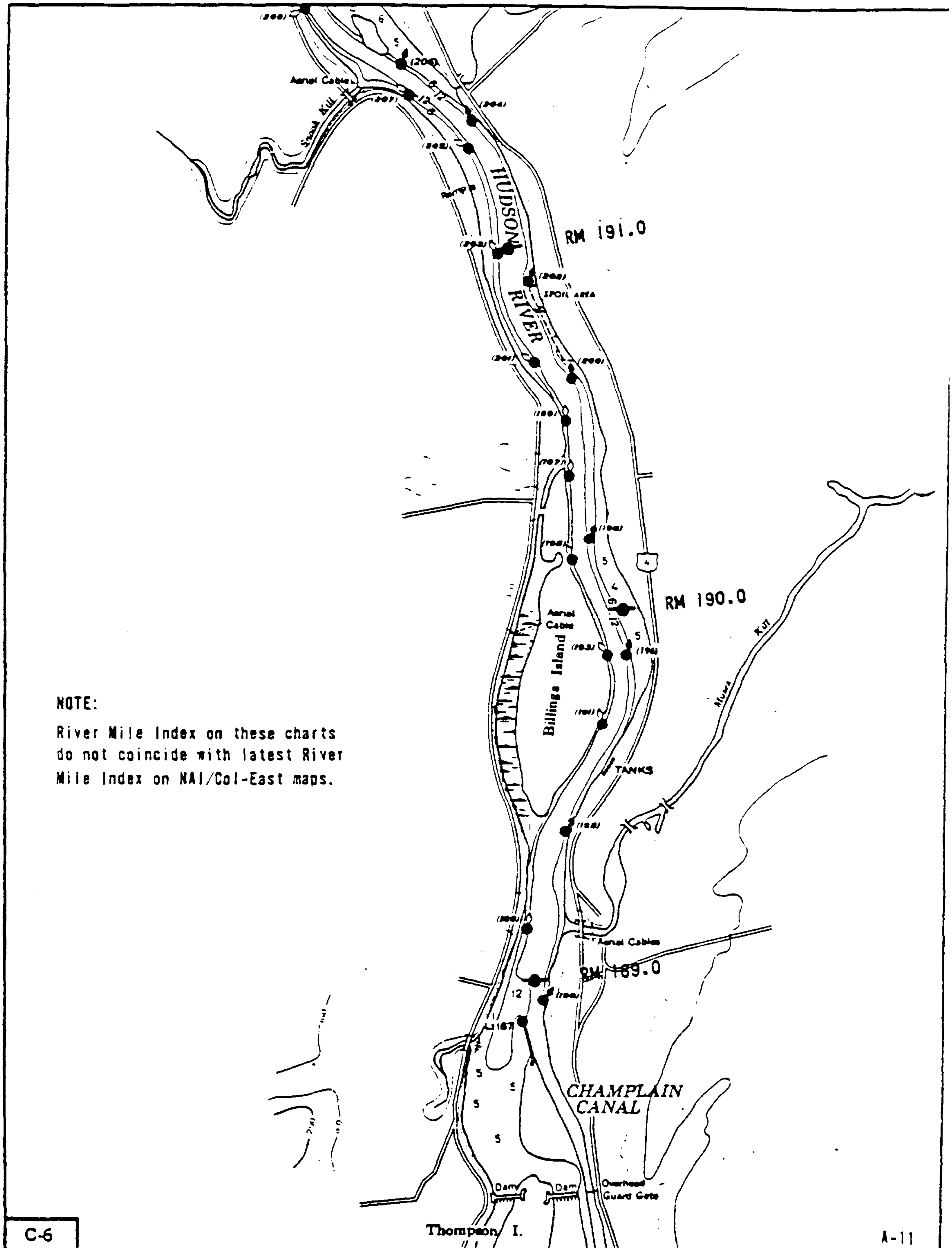

MONUMENT
SPIRE
SCHUYLERVILLE
Aerial Cable
Clearance 55 feet
RM 180.0
RM 179.0
RM 178.0
HUDSON
RIVER
Ramp
NOTE:
River Mile Index on these charts
do not coincide with latest River
Mile Index on NAI/Col-East maps.


RM 184.0
SPOIL AREA
BR.C-10
RM 183.5-
Thomson
Terminal
Water Control Gate
Northumberland
TANK
Dam
TANK
RM 183.1
RM 183.0
HUDSON
RM 182.4
STACK
Aerial Cable
Aerial Cables
Batten Kill
Lock 5
BR.C-6
RM 181.9
RIVER
SCHUYLERVILLE
Aerial Cable
P.O.
Aerial Cable
Schuylerville Yacht Basin
BR.C-7
MONUMENT
SPIRE
29
32
NOTE:
River Mile Index on these charts do not coincide with latest River Mile Index on NAI/Col-East maps.

NOTE:

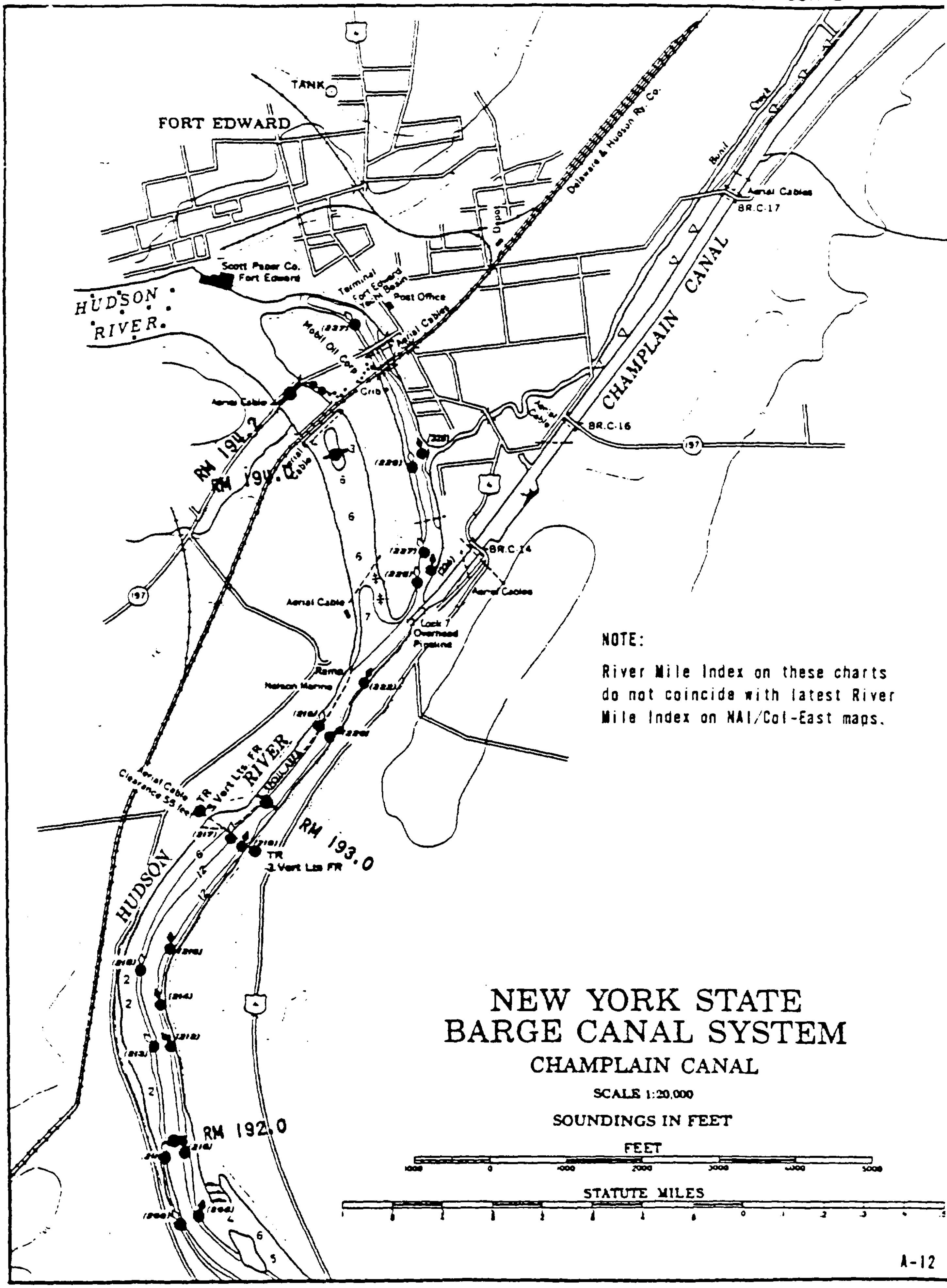
River Mile Index on these charts do not coincide with latest River Mile Index on NAI/Col-East maps.





NOTE:

River Mile Index on these charts do not coincide with latest River Mile Index on NAI/Col-East maps.


TANK
FORT EDWARD
Delaware & Hudson Ry. Co.
Aerial Cables
BR.C-17
CHAMPLAIN CANAL
Scott Paper Co.
Fort Edward
HUDSON RIVER
Terminal
Fort Edward Yacht Basin
Post Office
Mobil Oil Corp.
Aerial Cables
Crib
Aerial Cable
RM 194.2
RM 194.0
BR.C-16
197
BR.C-14
Aerial Cables
Aerial Cable
Lock 7
Overhead
Pipeline
NOTE:
River Mile Index on these charts
do not coincide with latest River
Mile Index on NAI/Col-East maps.
Ramp
Nelson Marina
RIVER
Aerial Cable TR
Clearance 55 feet
3 Vert Lts FR
RM 193.0
TR
3 Vert Lts FR
HUDSON
RM 192.0
NEW YORK STATE
BARGE CANAL SYSTEM
CHAMPLAIN CANAL
SCALE 1:20,000
SOUNDINGS IN FEET
FEET
STATUTE MILES

APPENDIX B

SAMPLE CALCULATIONS
REACH 8
THOMPSON ISLAND POOL (RM 188.5) - LOCK 7 (RM 193.7)

SAMPLE CALCUALTION
THOMPSON ISLAND DAM - LOCK 7
16" HYDRAULIC DREDGES
TO ONE DISPOSAL AREA

REACH PARAMETERS:

Total volume of material	1.72×10^6 cu yd
Disposal Site No.	10
RM of Disposal Site	191.9
Distance From Bank to Disposal Site	4000 ft
Maximum Lift	40 ft
Perimeter	12700 ft
Reach Length	5.2 mi
Average Reach Width	710 ft

EQUIPMENT REQUIRED:

1) 16 in. Dredges

production rate = 158,500 cu yd/mo

$$\frac{1.72 \times 10^6 \text{ cu yd}}{158{,}500 \text{ cu yd/mo}} = 10.86 \text{ Dredge Months}$$

Using 3 Dredges

$$\frac{10.86 \text{ dredge mo}}{3 \text{ dredges}} = 3.62 \text{ Calendar Months}$$

2) 16 in. Boosters

Reach is divided into 3 subreaches
1 Dredge/subreach

Compute pipeline lengths required

Subreach or Dredge	Site	Time mo	Maximum Pipeline ft	Average Pipeline ft
A	10	3.62	16,100	11,400
B	10	3.62	9,800	6,900
C	10	3.62	19,300	14,600
	return line		4,000	
	total	=	49,200	32,900

$$\text{weighted average pipeline} = \frac{\text{Sum (dredge mo x average pipeline)}}{\text{10.86 dredge mo}}$$

$$= 11{,}000 \text{ ft}$$

Compute boosters required for each subreach

Average Conditions
17 ft/sec
h_f = 5.61 ft per 100 ft
material factor = 1.25
suction = 24 ft
conversion factor to horse power @ 55% efficiency = 0.288

Dredge A to Site 10

$$\text{Head required} = (11{,}400 \times 1.25 \times \frac{5.61}{100}) + 24 + 40 = 867 \text{ ft Head}$$

Power required = 867 ft x 17 x 0.288 = 3500 HP

$$\frac{\text{3500 HP - 1500 HP/Dredge}}{\text{1200 HP/Booster}} = \text{2 Boosters}$$

Dredge B to Site 10

$$(6{,}900 \times 1.25 \times \frac{5.61}{100}) + 24 + 40 = 550 \text{ ft Head}$$

550 ft x 17 x 0.288 = 2680 HP

$$\frac{\text{2680 HP - 1500 HP/Dredge}}{\text{1200 HP/Booster}} = \text{1 Booster}$$

Dredge C to Site 10

$$(14{,}600 \times 1.24 \times \frac{5.61}{100}) + 40 + 24 + 1090 \text{ ft Head}$$

1090 ft x 17 x 0.288 = 5320 HP

$$\frac{\text{5320 HP - 1500 HP/dredge}}{\text{1200 HP/booster}} = \text{3 boosters}$$

Booster Operating & Ownership Months

Dredge A	2 Boosters	3.62 mo
Dredge B	1 Boosters	3.62 mo
Dredge C	3 Boosters	3.62 mo
	21.72 Booster mo	

3) Area Required:

$$\frac{1.72 \times 10^6 \text{ cu yd}}{1613 \ \frac{\text{cu yd}}{\text{acre ft}} \ 10 \text{ ft}} = 106.6 \text{ Acres}$$

20% Fines	=	21.3
+ 5 Treatment	=	5.0
		132.9 Acres

COST CALCULATIONS:

I Mobilization

A. General
3 Dredges @ $100,000 — 300,000

B. Laying Initial Lines
49,200 ft @ $4.50 — 220,000

520,000

II Site Acquisition
A. 132.9 Acres @ $2,000 — 270,000

III Site Preparation

A. Diking
12,700 ft perimeter site 10
3,200 ft 25% cross dikes
15,900 ft 20 $\frac{\text{cu yd}}{\text{ft}}$ @ $ 6 — 1,800,000
- $107,000 Treatment Dikes

	B.	Wiers 2 wiers/site x 1 site @ $12,000	24,000	
	C.	Clearing & Grubbing 132.9 acres 25% @ $1,000	30,000	
				1,850,000
IV		Dredging & Transport		
	A.	Dredge Operating Cost unit cost $224,609 pipeline wear $ 11,000 10.86 dredge mo @ $235,600	2,560,000	
	B.	Dredge Ownership 10.86 dredge mo @ $40,000	430,000	
	C.	Booster Operating 21.72 booster mo @ $46,000	1,000,000	
	D.	Booster Ownership 21.72 booster mo @ $10,000	200,000	
	E.	Supervision & Engineering 4.2 mo x 3 dredges @ $9,000	110,000	
	F.	Overhead & Profit @ 35%	1,510,000	
	G.	Drift Boom 500 ft/dredge x 3 dredges @ $20	30,000	
	H.	Pipeline Easement 49,200 ft @ $ 575/1000 ft	30,000	
				5,890,000

V	Site Restoration		
	A. Cover 18 in clay 132.9 acre 43560 $\frac{\text{sq ft}}{\text{acre}}$ x 1.5 ft $\frac{\text{cu yd}}{\text{27 cu ft}}$ @ $6	1,930,000	
	B. Turf Establishment - 18 in 132.9 acre 43569 $\frac{\text{sq ft}}{\text{acre}}$ x 1.5 ft $\frac{\text{cu yd}}{\text{27 cu ft}}$ @ $3	960,000	
	C. Seeding & Mulching 132.9 acres @ $1,000	130,000	
			3,020,000
VI	Dredging Control		
	A. PCB Testing 5.2 mi (5280 $\frac{\text{ft}}{\text{mi}}$) 710 ft @ $\frac{\$15}{100 \times 100 \text{ sq ft}}$	30,000	
	B. Dredge Control 10.86 dredge mo @ $37,500	410,000	
			440,000
	Subtotal Without Treatment		$11,990,000
VII	Return Flow Treatment		
	A. Sedimentation & Coagulation $677,000		677,000
	Subtotal Including Treatment By Sedimentation & Coagulation		$12,667,000
VIII	Contingencies @ 20%		2,530,000
IX	Engineering		630,000
X	Legal & Administrative		250,000
	Total Including Treatment By Sedimentation & Coagulation		$16,077,000

VIIB	Treatment Including Filtration-Adsorption			
	A.	Sedimentation $677,000	677,000	
	B.	Carbon Adsorption $10,250,000 - 38 MGD	10,250,000	
				10,927,000
		Subtotal Including Treatment with Filtration - Adsorption		$22,917,000
VIIIB	Contingencies @ 20%			4,580,000
IXB	Engineering			1,140,000
XB	Legal & Administrative			460,000
		Total Including Treatment with Filtration - Adsorption		$29,097,000

SAMPLE CALCUALTION
THOMPSON ISLAND DAM - LOCK 7
16" HYDRAULIC DREDGES
TO 3 DISPOSAL AREAS

REACH PARAMETERS:

Total volume of material 1.72×10^6 cu yd

Disposal Site No.	4	8	10
Volume to Disposal Site (cu yd)	574,000	573,000	573,000
RM of Disposal Site	192.5	189.0	191.0
Distance From Bank to Disposal Site (ft)	3000	4000	4000
Maximum Lift (ft)	50	110	40
Perimeter (ft)	5200	4300	6200

Reach Length 5.2 mi
Average Reach Width 710 ft

EQUIPMENT REQUIRED:

1) 16 in. Dredges
production rate = 158,500 cu yd/mo

$$\frac{1.72 \times 10^6 \text{ cu yd}}{158{,}500 \text{ cu yd/mo}} = 10.86 \text{ Dredge Months}$$

Using 3 Dredges

$$\frac{10.86 \text{ dredge mo}}{3 \text{ dredges}} = 3.62 \text{ Calendar Months}$$

2) 16 in. Boosters
Reach is Divided Into 3 Subreaches
(1 Dredge/Subreach)

Compute pipeline lengths required

Dredge	Site	Time mo	Maximum Pipeline ft	Average Pipeline ft
A	8	3.62	14,300	7,800
B	10	3.62	12,800	5,400
C	4	3.62	12,300	6,200
		Total =	39,400	18,800

$$\text{weighted average pipeline} = \frac{\text{Sum (dredge mo x average pipeline)}}{10.86 \text{ dredge mo}}$$

$$= 6{,}300 \text{ ft}$$

Compute boosters required for each subreach

Average Conditions
17 ft/sec
h_f = 5.61 ft/1000 ft
material factor = 1.25
suction = 24 ft
conversion factor to horse power @ 55% efficiency = 0.288

Dredge A to Site 8

$$\text{Head required} = (7{,}200 \times 1.25 \times \frac{5.61}{100}) + 24 + 110 = 640 \text{ ft Head}$$

Power required = 640 ft x 17 x 0.288 = 3130 HP

$$\frac{3130 \text{ HP} - 1500 \text{ HP/Dredge}}{1200 \text{ HP/Booster}} = 1 \text{ Booster}$$

Dredge B to Site 10

$$(5{,}400 \times 1.25 \times \frac{5.61}{100}) + 24 + 40 = 440 \text{ ft Head}$$

440 ft x 17 x 0.288 = 2150 HP

$$\frac{2150 \text{ HP} - 1500 \text{ HP/Dredge}}{1200 \text{ HP/Booster}} = 1 \text{ Booster}$$

Dredge C to Site 4

$$(6{,}200 \times 1.25 \times \frac{5.61}{100}) + 24 + 50 = 510 \text{ ft Head}$$

510 ft x 17 x 0.288 = 2490 HP

$$\frac{2490 \text{ HP} - 1500 \text{ HP/Dredge}}{1200 \text{ HP/Booster}} = 1 \text{ Booster}$$

Booster Ownership & Operating Months

Dredge A	1 Booster	3.62 mo
Dredge B	1 Booster	3.62 mo
Dredge C	1 Booster	3.62 mo
		10.86 Booster month

3) Area Required:

$$\frac{1.72 \times 10^6 \text{ cu yd}}{1613 \frac{\text{cu yd}}{\text{acre-ft}} \text{ 10 ft}} = 106.6 \text{ Acres}$$

20% Fines	=	21.3
+ 5 Treatment	=	5.0
		132.9 Acres

COST CALCULATIONS:

I Mobilization:

A. General

3 Dredges @ $100,000 — 300,000

B. Laying Initial Lines

39,400 ft @ $4.50 — 180,000

480,000

II Site Acquisition

A. 132.9 acres @ $2,000 — 270,000

III Site Preparation

A. Diking

5200	ft Perimeter Site 4
4300	ft Perimeter Site 8
6200	ft Perimeter Site 10
15,700	
3900	25% cross dikes
19,600	ft 20 $\frac{\text{cu yd}}{\text{ft}}$ @ $6 — 2,250,000

- $107,000 Treatment Dikes

	B.	Wiers 2 wiers/site x 3 sites @ $12,000	70,000	
	C.	Clearing & Grubbing 132.0 acres 25% @ $1,000	30,000	
				2,350,000
IV		Dredging & Transport		
	A.	Dredge operating unit cost $224,609 pipeline wear 6,300 10.86 dredge mo @ $230,909	2,510,000	
	B.	Dredge Ownership 10.86 dredge mo @ $40,000	430,000	
	C.	Booster Operating 10.86 booster mo @ $46,000	500,000	
	D.	Booster Ownership 10.86 booster mo @ $10,000	110,000	
	E.	Supervision & Engineering 4.2 mo x 3 dredges @ $9,000	110,000	
	F.	Overhead & Profit @ 35%	1,280,000	
	G.	Drift Boom 500 ft/dredge x 3 dredges @ $20	30,000	
	H.	Pipeline Easement 39,400 ft @ $ 575/1000 ft	20,000	
				4,990,000

V	Site Restoration		
	A. Cover - 18 in clay 132.9 acres 43560 $\frac{\text{sq ft}}{\text{acre}}$ x 1.5 ft $\frac{\text{cu yd}}{27 \text{ cu ft}}$ @ $6	1,930,000	
	B. Turf Establishment - 18 in 132.9 acre 43560 $\frac{\text{sq ft}}{\text{acre}}$ x 1.5 ft $\frac{\text{cu yd}}{27 \text{ cu ft}}$ @ $3	960,000	
	C. Seeding & Mulching 132.9 acres @ $1,000	130,000	
			3,020,000
VI	Dredging Control		
	A. PCB Testing 5.2 mi (5280 $\frac{\text{ft}}{\text{mi}}$) 710 ft @ $\frac{\$15}{100\text{x}100 \text{ sq ft}}$	30,000	
	B. Dredge Control 10.86 dredge mo @ $37,500	410,000	
			440,000
	Subtotal Without Treatment		$11,550,000
VII	Return Flow Teatment		
	A. Sedimentation & Coagulation $677,000		677,000
	Subtotal Including Treatment By Sedimentation & Coagulation		$12,227,000
VIII	Contingencies @ 20%		2,450,000
IX	Engineering		610,000
X	Legal & Administrative		240,000
	Total Including Treatment By Sedimentation & Coagulation		$15,527,000

XIB	Treatment Including Filtration - Adsorption		
	A. Sedimentation $677,000	677,000	
	B. Carbon Adsorption 10,250,000 - 38 MGD	10,250,000	
			10,927,000
		Subtotal Including Treatment with Filtration - Adsorption	$22,477,000
XIIB	Contingencies @ 20%		4,500,000
XIIB	Engineering		1,120,000
XIVB	Legal & Administrative		450,000
		Total Including Treatment with Filtration - Adsoption	$28,547,000

SAMPLE CALCULATION
THOMPSON ISLAND DAM - LOCK 7
12" HYDRAULIC DREDGES TO 4 DISPOSAL AREAS

REACH PARAMETERS:

Total volume of material 1.72×10^6 cu yd

Disposal Site No.	4	5	8	10
Volume to Disposal Site (cu yd)	573,000	287,000	287,000	573,000
Maximum Pipeline (ft)	6,000	5,000	6,000	6,000
Average Pipeline (ft)	4,500	3,000	4,500	3,500
Maximum Lift (ft)	80	30	100	40
Perimeter (ft)	4,300	3,600	3,100	3,800

Reach Length 5.2 mi
Average Reach Width 710 ft

EQUIPMENT REQUIRED:

1) 12 in. Dredges & Boosters

at maximum conditions

14 ft/sec
h_f = 5.61 ft per 100 ft
suction = 20 ft
material factor = 1.25
conversion factor to horse power @ 55% efficiency = 0.162

Site 8

$$\text{Head required} = (6{,}000 \times 1.25 \times \frac{5.61}{100}) + 20 + 100 = 540 \text{ ft Head}$$

Power required = 540 ft x 14 (0.162) = 1225 HP

$$\frac{1225 \text{ HP} - 800 \text{ HP/dredge}}{500 \text{ HP/Booster}} = 1 \text{ Booster}$$

Average Conditions

Site #4

16 ft/sec
h_f = 7.18 ft per 100 ft
suction = 20 ft
material factor = 1.25
conversion factor to horsepower @ 55% efficiency = 0.162

$$(4{,}500 \times 1.25 \times \frac{7.18}{100}) + 20 + 80 = 504 \text{ ft head}$$

$$504 \text{ ft} \times 16 \times (0.162) = 1306 \text{ HP}$$

$$\frac{1306 - 800 \text{ HP/dredge}}{500 \text{ HP/Booster}} = 1 \text{ Booster}$$

Average Production
16 x 10.48 x 500 = 84,000 cu yd/mo

$$\frac{573{,}000 \text{ cu yd}}{84{,}000 \text{ cu yd/mo}} = 6.82 \text{ dredge mo}$$

6.82 booster mo

Site #10

18 ft/sec
h_f = 8.94 ft/100 ft
suction = 20 ft
material factor = 1.25
conversion factor to horsepower @ 55% efficiency = 0.162

$$(3{,}500 \times 1.25 \times \frac{8.94}{100}) + 20 + 40 = 451 \text{ ft head}$$

$$451 \text{ ft} \times 18 \times 0.162 = 1315 \text{ HP}$$

$$\frac{1315 \text{ HP} - 800 \text{ HP/dredge}}{500 \text{ HP/Booster}} = 1 \text{ Booster}$$

Average Production
18 x 10.48 x 500 = 94,000 cu yd/mo

$$\frac{573{,}000 \text{ cu yd}}{94{,}000 \text{ cy yd/mo}} = 6.06 \text{ dredge mo}$$

6.06 booster mo

Site #5

16 ft/sec

h_f = 7.18 ft/100 ft

suction = 20 ft

material factor = 1.25

conversion factor to horsepower @ 55% efficiency = 0.162

$$(3{,}000 \times 1.25 \times \frac{7.18}{100}) + 20 + 30 = 319 \text{ ft head}$$

319 ft x 16 x (0.162) = 826 HP

$$\frac{826 \text{ HP} - 800 \text{ HP/dredge}}{500 \text{ HP/Booster}} = 0 \text{ Boosters}$$

Average Production

16 x 10.48 x 500 = 84000 cu yd/mo

$$\frac{287{,}000 \text{ cu yd}}{84{,}000 \text{ cu yd/mo}} = 3.42 \text{ dredge mo}$$

0.0 booster mo

Site #8

15.5 ft/sec

h_f = 6.77 ft/100 ft

suction = 20 ft

material factor = 1.25

conversion factor to horsepower @ 55% efficiency = 0.162

$$(4{,}500 \times 1.25 \times \frac{6.77}{100}) + 100 + 20 = 500 \text{ ft head}$$

500 ft x 15.5 x (0.162) = 1255 HP

$$\frac{1255 - 800 \text{ HP/dredge}}{500 \text{ HP/Booster}} = 1 \text{ Booster}$$

Average Producton

15.5 x 10.48 x 500 = 81,000 cu yd/mo

$$\frac{287{,}000 \text{ cu yd}}{81{,}000 \text{ cu yd/mo}} = 3.53 \text{ dredge mo}$$

3.53 booster mo

Total Dredge months

6.82	
6.06	
3.42	
3.53	
19.83	dredge mo

$$\frac{19.83 \text{ dredge mo}}{4 \text{ dredges}} = 4.96 \text{ calendar months}$$

Total booster months

6.82	
6.06	
3.53	
16.41	booster mo

2) Area required

$$\frac{1.72 \times 10^{6} \text{ cu yd}}{1613 \frac{\text{cu yd}}{\text{acre-ft}} 10 \text{ ft}} = 106.6 \text{ acres}$$

20% fines	=	21.3
+ 5 treatment	=	5.0
		132.9 acres

COST CALCULATIONS

I Mobilization

A. General

4 dredges @ $80,000	320,000	

B. Laying Initial Lines

6,000 ft	Site 4		
5,000 ft	Site 5		
6,000 ft	Site 8		
6,000 ft	Site 10		
6,000	return lines		
29,000	ft @ $4.50	130,000	
			450,000

II	Site Acquisition		
	A. 132.9 acres @ $2,000		270,000
III	Site Preparation		
	A. Diking		
	4,300 ft perimeter Site 4		
	3,600 ft perimeter Site 5		
	3,100 ft perimeter Site 8		
	3,800 ft perimeter Site 10		
	14,800 ft		
	3,700 25% cross dikes		
	18,500 ft 20 cu yd/ft @ $6		
	- 4 ($50,000)		
	Treatment Dikes	2,020,000	
	B. Wiers		
	2 wiers/site x 4 sites @ $3,000	24,000	
	C. Clearing & Grubbing		
	132.9 acres @ 25% @ 1000	30,000	
			2,070,000
IV	Dredging & Transport		
	A. Dredge Operating		
	Unit cost $ 85,751		
	Pipeline wear $ 38,820		
	19.83 dredge mo @ $124,571	2,470,000	
	B. Dredge Ownership		
	19.83 dredge mo @ $12,000	240,000	
	C. Booster Operating		
	16.41 booster mo @ $33,824	560,000	
	D. Booster Ownership		
	16.41 booster mo $ 5,000	80,000	

	E.	Supervision & Engineering 5.8 mo @ $27,000	160,000	
	F.	Overhead & Profit @ 35%	1,230,000	
	G.	Drift Boom 500 $\frac{ft}{dredge}$ x 4 dredges @ $20	40,000	
	H.	Pipeline Easement 29,000 ft @ $ $\frac{575}{1000\ ft}$	20,000	
				4,800,000
V		Site Restoration		
	A.	Cover 18 in clay 132.9 acre 43560 $\frac{sq\ ft}{acre}$ 1.5 ft $\frac{cu\ yd}{27\ cu\ ft}$ @ $6	1,930,000	
	B.	Turf Establishment 18 in 132.9 acre 43560 $\frac{sq\ ft}{acre}$ 1.5 ft $\frac{cu\ yd}{27\ cu\ ft}$ @ $6	960,000	
	C.	Seeding & Mulching 132.9 acre @ $1,000	130,000	
				3,020,000
VI		Dredge Control		
	A.	PCB Testing 5.2 mi (5280 $\frac{ft}{mi}$) 710 ft @ $ $\frac{15}{100 \times 100\ sq\ ft}$	30,000	
	B.	Dredge Control 19.83 dredge mo @ $37,500	740,000	
				770,000
		Subtotal Without Treatment Costs		$11,380,000

VII	Return Flow Treatment		
	A. Sedimentation & Coagulation 4 @ $236,000		940,000
	Subtotal Including Treatment By Sedimentation & Coagulation		$12,320,000
VIII	Contingencies @ 20%		2,460,000
IX	Engineering		620,000
X	Legal & Administrative		250,000
	Total Including Treatment By Sedimentation & Coagulation		$15,650,000
VIIB	Treatment Including Filtration - Adsorption		
	A. Sedimentation 4 @ $236,000	940,000	
	B. Carbon Adsorption 4 @ $1,400,000	5,600,000	6,540,000
	Subtotal Including Treatment with Filtration - Adsorption		$17,920,000
VIII	Contingencies @ 20%		3,580,000
IX	Engineering		900,000
X	Legal & Administrative		360,000
	Total Including Treatment with Filtration - Adsorption		$22,760,000

SAMPLE CALCULATION
THOMPSON ISLAND DAM - LOCK 7
CLAMSHELL EXCAVATION - HYDRAULIC UNLOADING
TO ONE DISPOSAL AREA

REACH PARAMETERS:

Disposal Site No.	12
Total Volume of Material	1.72×10^6 cu yd
Rehandling Area	RM 190.3
Maximum One-way Tow	3.4 mi
Average One-way Tow	1.7 mi
Number of Locks to Pass	0
Maximum Pipeline	12000 ft
Average Pipeline	6000 ft
Maximum Lift	40 ft
Perimeter	12700 ft
Reach Length	5.2 mi
Average Reach Width	710 ft

EQUIPMENT REQUIRED:

1) Clamshell Dredges

production rate = 120,000 cu yd/mo

$$\frac{1.72 \times 10^6 \text{ cu yd}}{120{,}000 \text{ cu yd/mo}} = 14.33 \text{ dredge months}$$

Using 3 Dredges

$$\frac{14.33 \text{ dredge mo}}{3 \text{ dredges}} = 4.8 \text{ Calendar Months}$$

2) Scows

Maximum Round Trip Time

$$\text{travel time } \frac{2\ (3.4\text{mi})}{4 \text{ knots}} = 1.7 \text{ hrs}$$

tying up @ 0.5 hr = 0.5
passing locks @ 0.5 hr = ---
2.2 hrs

Average round trip time

travel time $\frac{2\ (1.7)}{4\ \text{knots}}$ 0.85 hr

tying up @ 0.5 hr 0.5

passing locks @ 0.5 hr --

1.35 hr

Average round trip time $\frac{1.35 + 2.2}{2} = 1.78$ hrs

Loading time = $\frac{1000\ \text{cu yd scow}}{200\ \text{cu yd/hr}} = 5$ hr

Unloading time = $\frac{1000\ \text{cu yd scow}}{312\ \text{cu yd/hr}} = 3.2$ hr

Round trip time + unloading time = loading time

1.78 + 3.2 = 4.98 hrs

0-5 hr use 2 scows/dredge

5-10 hr use 3 scows/dredge

$2\ \frac{\text{scows}}{\text{dredge}} \times 3$ dredges = 6 scows

3) Tugs - Tenders

1 tug / moving scow

6 scows - 3 loading - 1 unloading = 2 tugs

1 tender/dredge

3 dredges $1\ \frac{\text{tender}}{\text{dredge}}$ = 3 tenders

4) 27 in. Pump out units

must handle 3 (120,000) cu yd/mo average

3 (150,000) cu yd/mo maximum

required $\dfrac{450{,}000 \text{ cu yd/mo}}{400 \text{ hr/mo pumping}}$ = 1125 cu yd/hr

Average conditions

17 ft/sec

h_f = 2.91 ft/100 ft

suction = 24 ft

material factor = 1.25

conversion factor to horsepower @ 55% efficiency = 0.822

$(6000 \times 1.25 \times \frac{2.91}{100}) + 24 + 40 = 280$ ft/head

$280 \text{ ft} \times 17 \times 0.822 = 3910$ HP

$17\ (53.07)\ 1.5 = 1353$ cu yd/hr

$\dfrac{1353 \text{ cu yd/hr}}{\text{required } 1125 \text{ cu yd/hr}}$ = 1 27 in. pump out unit

5) Area Required

$\dfrac{1.72 \times 10^6 \text{ cu yd}}{1613 \frac{\text{cu yd}}{\text{acre ft}}\ 10 \text{ ft}} = 106.6$ acres

20% fines	=	21.3
+ 5 treatment	=	5
		132.9 acres

COST CALCULATIONS:

I.	Mobilization		
	A. General		
	Sum at pieces of equipment @ $17,650		
	3 dredges		
	2 tugs		
	3 tenders		
	6 scows		
	1 pump out unit		
	1 hopper-conveyor barge		
	16 pieces @ $17,650	280,000	
	B. Laying Initial lines		
	12,000 @ $4.50	50,000	
			330,000
II	Site Acquisition		
	A. 132.9 acres @ $2,000		270,000
III	Site Preparation		
	A. Diking		
	12,700 ft perimeter		
	3,200 25% cross dikes		
	15,900 ft 20 $\frac{\text{cu yd}}{\text{ft}}$ @ $6		
	- $107,000 treatment dikes	1,800,000	
	B. Wiers		
	2 $\frac{\text{wiers}}{\text{site}}$ x 1 site @ $12,000	24,000	
	C. Clearing & Grubbing		
	132.9 acres 25% @ $1,000	30,000	
			1,850,000

IV	Dredging & Transport		
	A. Pumping for pump-out		12,000
	B. Clamshell Operating		
	14.33 dredge mo	@ $72,280	1,040,000
	C. Clamshell Ownership		
	14.33 dredge mo	@ $30,000	430,000
	D. Pump-out Operating		
	unit cost	$165,985	
	pipeline wear	$ 43,500	
	4.8 mo	@ $209,485	1,000,000
	E. Pump-out Ownership		
	4.8 mo	@ $50,000	240,000
	F. Tugs-Tenders Operating		
	4.8 mo (2 tugs)	@ $43,309	
	4.8 mo (3 tenders)	@ $24,980	790,000
	G. Tugs-tenders Ownership		
	4.8 mo (2 tugs)	@ $8,000	
	4.8 mo (3 tenders)	@ $4,000	130,000
	H. Scows Ownership		
	4.8 mo (6 scows)	@ $2,000	60,000
	I. Scows Operating		
	4.8 mo (6 scows)	@ $12,000	340,000
	J. Hopper-Conveyor Barge Operating		
	4.8 mo	@ $22,962	110,000
	K. Hopper-Conveyor Barge Ownership		
	4.8 mo	@ $15,000	70,000
	L. Supervision & Engineering		
	5.5 mo x 3 dredges	@ $9,000	150,000
	M. Overhead & Profit		
	@ 35%		1,530,000

	N. Drift Boom 500 $\frac{ft}{dredge}$ x 3 dredges @ \$20	30,000	
			5,930,000
V	Site Restoration A. Cover 18 in. clay 132.9 acres 43560 $\frac{sq\ ft}{acre}$ x 1.5 ft $\frac{cu\ yd}{27\ cu\ ft}$ @ \$6	1,930,000	
	B. Turf Establishment 18 in. 132.9 acres 43560 $\frac{sq\ ft}{acre}$ x 1.5 ft $\frac{cu\ yd}{27\ cu\ ft}$ @ \$3	960,000	
	C. Seeding & Mulching 132.9 acres @ \$1,000	130,000	
			3,020,000
VI	Dredging Control A. PCB Testing 5.2 mi (5280 $\frac{ft}{mi}$) 710 ft @ $\frac{\$15}{100 \times 100\ sq\ ft}$	30,000	
	B. Dredge Control 14.33 dredge mo @ \$37,500	537,000	
			570,000
	Subtotal Without Treatment Costs		\$11,970,000
VII	Return Flow Treatment A. Sedimentation & Coagulation \$677,000		677,000
	Subtotal Including Treatment By Sedimentation & Coagulation		\$12,647,000

XII	Contingencies @ 20%		2,530,000
XIII	Engineering		630,000
XIV	Legal & Administrative		250,000
	Total Including Treatment By Sedimentation & Coagulation		$16,057,000
XIB	Treatment Including Filtration - Adsorption		
	A. Sedimentation $677,000	677,000	
	B. Carbon Adsorption $10,250,000 38 MGD	10,250,000	
			10,927,000
	Subtotal Including Treatment with Filtration - Adsorption		$22,897,000
XIIB	Contingencies @ 20%		4,580,000
XIIB	Engineering		1,140,000
XIVB	Legal & Administrative		460,000
	Total Including Treatment with Filtration - Adsoption		$29,077,000

SAMPLE CALCULATION
THOMPSON ISLAND DAM - LOCK 7
CLAMSHELL EXCAVATION - MECHANICAL UNLOADING
ONE DISPOSAL AREA

REACH PARAMETERS:

Disposal Site No.	12
Total Volume of Material	1.72×10^6 cu yd
Rehandling Area	RM 190.3
Maximum One-Way Tow	3.4 mi
Average One-Way Tow	1.7 mi
Number of Locks to Pass	0
Trucking Distance	1.5 mi
Perimeter Factor	0.0043 ft/cu yd
Reach Length	5.2 mi
Reach Width (Ave)	710 ft

EQUIPMENT REQUIRED:

1) Clamshell Dredges

production rate = 120,000 cu yd/mo

$$\frac{1.72 \times 10^6 \text{ cy yd}}{120{,}000 \text{ cy yd/mo}} = 14.33 \text{ dredge months}$$

Using 3 Dredges

$$\frac{14.33 \text{ dredge mo}}{3 \text{ dredges}} = 4.8 \text{ calendar mo}$$

2) Scows

Maximum round trip time

travel time $2 \frac{(3.4) \text{ mi}}{4 \text{ knots}}$	=	1.7 hrs
tying up @ 0.5 hr		0.5
passing locks @ 0.5 hrs		---
		2.2 hr

Average round trip time

travel time	$\frac{2\ (1.7)}{4\ \text{knots}}$	0.85 hr
tying up	@ 0.5 hr	0.5
passing locks	@ 0.5 hr	---
		1.35 hrs

Average round trip time $\frac{1.35 + 2.2}{2} = 1.78$ hrs

Loading Time = $\frac{1000 \text{ cu yd/scow}}{200 \text{ cu yd/hr}}$ = 5 hr

Unloading time = $\frac{1000 \text{ cu yd/scow}}{312 \text{ cu yd/hr}}$ = 3.2 hrs

Round trip time + unloading time = loading time

1.78 + 3.2 = 4.98 hrs

0-5 hrs	use 2 scows/dredge
5-10 hrs	use 3 scows/dredge
10-15 hrs	use 4 scows/dredge
15-20 hrs	use 5 scows/dredge
20-25 hrs	use 6 scows/dredge

$2 \frac{\text{scows}}{\text{dredge}} \times 3$ dredges = 6 scows

3) Tugs - Tenders

1 tug/ 1 moving scow
6 scows - 3 loading - 1 unloading = 2 tugs

1 tender/dredge

$1 \frac{\text{tender}}{\text{dredge}}$ 3 dredges = 3 tenders

4) Rehandling Units

production rate = 196,500 cu yd/mo

$$\frac{3 \text{ dredges} \times 120{,}000 \text{ cu yd/mo/dredge}}{196{,}500 \text{ cu yd/mo unit}} = 1.8$$

use 2 units

5) Area Required

1.72×10^6 cu yd x 1.2 (swell factor) = 2.064×10^6 cu yd

$$\frac{2.064 \times 10^6 \text{ cu yd}}{1613 \frac{\text{cu yd}}{\text{acre ft}} 15 \text{ ft}} = 85.3 \text{ acres}$$

COST CALCULATIONS:

I. Mobilization

A. Sum at pieces of equipment @ $17,650

3	dredges	
6	scows	
2	tugs	
3	tenders	
2	rehandling units	
1	hopper-conveyor barge	
17	pieces @ $17,650	300,000

II. Site Acquisition

A. 85.3 acres @ $2,000 — 170,000

III Site Preparation

A. Diking - toe dikes

1.72×10^6 cu yd $0.0043 \frac{\text{ft}}{\text{cu yd}} \times \frac{4 \text{ cu yd}}{\text{ft}}$ @ $6 — 180,000

B. Clearing & Grubbing

85.3 acres 25% @ $1000 — 20,000

200,000

IV	Dredging & Transport	
	A. Clamshell Operating 14.33 dredge mo @ $72,280	1,040,000
	B. Clamshell Ownership 14.33 dredge mo @ $30,000	430,000
	C. Tugs - Tenders Operating 4.8 mo (2 tugs) @ $43,309 4.8 mo (3 tenders) @ $25,980	790,000
	D. Tugs - Tenders Ownership 4.8 mo (2 tugs) @ $8,000 4.8 mo (3 tenders) @ $4,000	130,000
	E. Scows Operating 4.8 mo (6 scows) @ $2,000	60,000
	F. Scows Ownership 4.8 mo (6 scows) @ $12,000	340,000
	G. Hopper Conveyor Barge Operating 4.8 mo @ $22,962	110,000
	H. Hopper Conveyor Barge Ownership 4.8 mo @ $15,000	70,000
	I. Rehandling Clamshells Operating 4.8 mo (2 units) @ $27,500	260,000
	J. Rehandling Clamshell Ownership 4.8 mo (2 units) @ $25,000	240,000
	K. Prepare Rehandling Area ($\$200{,}000 + \frac{\$16{,}700}{\text{dredge}} \times 3$ dredges)	250,000
	L. Loading, Hauling, Spreading $2/ cu yd mi + $0.15 each additional mile > 1.5 mi 1.72×10^6 cu yd @ $2.00	3,440,000

M.	Supervision & Engineering 5.5 mo x 3 dredges @ $9,000	150,000	
N.	Overhead & Profit @ 35%	2,560,000	
O.	Drift Boom 500 $\frac{\text{ft}}{\text{dredge}}$ x 3 dredges @ $20	30,000	
			9,900,000
V	Site Restoration		
A.	Cover 18 in clay 85.3 acres 43560 $\frac{\text{sq ft}}{\text{acre}}$ 1.5 ft $\frac{\text{cu yd}}{27 \text{ cu ft}}$ @ $6	1,240,000	
B.	Turf Establishment - 18 85.3 acres 43560 $\frac{\text{sq ft}}{\text{acre}}$ 1.5 ft $\frac{\text{cu yd}}{27 \text{ cu ft}}$ @ $3	620,000	
C.	Seeding & Mulching 85.3 acres @ $1,000	90,000	
			1,950,000
VI	Dredging Control		
A.	PCB Testing 5.2 mi (5280 $\frac{\text{ft}}{\text{mi}}$) 710 ft @ $\frac{\$15}{100 \times 100 \text{ sq ft}}$	30,000	
B.	Dredge Control 14.33 dredge mo @ $37,500	537,000	
			570,000
	Subtotal Without Treatment		$13,090,000

VII	Return Flow Treatment A. Sedimentation & Coagulation @ $220,000		220,000
	Subtotal Including Treatment By Sedimentation & Coagulation		$13,310,000
XII	Contingencies @ 20%		2,660,000
XIII	Engineering		670,000
XIV	Legal & Administrative		270,000
	Total Including Treatment By Sedimentation & Coagulation		$16,910,000
XIB	Treatment Including Filtration - Adsorption		
	A. Sedimentation @ $220,000	220,000	
	B. Carbon Adsorption @ $500,000	500,000	
			720,000
	Subtotal Including Treatment with Filtration - Adsorption		$13,810,000
XIIB	Contingencies @ 20%		2,760,000
XIIB	Engineering		690,000
XIVB	Legal & Administrative		280,000
	Total Including Treatment with Filtration - Adsoption		$17,540,000

APPENDIX C

SAMPLE CALCULATION AND COST ESTIMATES
ALTERNATIVE 1
COMPLETE REMOVAL
HYDRAULIC DREDGING TO MULTIPLE DISPOSAL SITES

SAMPLE CALCULATION
REACH 1
FEDERAL DAM (RM 153.9) - LOCK 1 (RM 159.4)

REACH PARAMETERS:

Total volume of material	2.18×10^6 cu yd		
Disposal Site No.	26	27	29
Volume to Disposal Site (cu yd)	457,000	503,000	1,220,000
RM of Disposal Site	160.9	160.8	159.7
Distance From Bank to Disposal Site (ft)	1000	9000	2000
Maximum Lift (ft)	20	225	20
Perimeter (ft)	4800	5400	9000

Reach Length 5.5 mi
Average Reach Width 845 ft

EQUIPMENT REQUIRED:

1) 16 in. Dredges

production rate = 158,500 cu yd/mo

$$\frac{2.18 \times 10^6 \text{ cu yd}}{158,500 \text{ cu yd/mo}} = 13.75 \text{ Dredge Months}$$

Using 3 Dredges

$$\frac{13.75 \text{ dredge mo}}{3 \text{ dredges}} = 4.58 \text{ Calendar Months}$$

2) 16 in. Boosters

Reach is Divided Into 3 Subreaches
1 Dredge/Subreach

Subreach or Dredge	Subreach RM	Time To Site 29	26	27
A	153.9-155.7	4.58 mo		
B	155.7-157.5	3.12 mo	1.46 mo	
C	157.5-159.4		1.42 mo	3.16 mo

Compute pipeline lengths required

Dredge	Site	Time mo	Maximum Pipeline ft	Average Pipeline ft
A	29	4.58	34,600	27,800
B	29	3.12	25,100	17,800
B	26	1.46	29,500	23,200
C	26	1.42	4,000	13,700
C	27	3.16	34,900	21,100
			128,100	103,600

$$\text{weighted average pipeline} = \frac{\text{Sum (dredge mo x average pipeline)}}{\text{13.75 dredge mo}}$$

$$= 20{,}000 \text{ ft}$$

Compute boosters required for each subreach

Average Conditions
17 ft/sec
h_f = 5.61 ft per 100 ft
material factor = 1.25
suction = 24 ft
conversion factor to horse power @ 55% efficiency = 0.288

Dredge A to Site 29

$$\text{Head required} = (27{,}800 \times 1.25 \times \frac{5.61}{100}) + 24 + 20 = 1990 \text{ ft Head}$$

Power required = 1990 ft x 17 x 0.288 = 9740 HP

$$\frac{9740 \text{ HP} - 1500 \text{ HP/Dredge}}{1200 \text{ HP/Booster}} = 7 \text{ Boosters}$$

Dredge B to Site 29

$$(17{,}800 \times 1.25 \times \frac{5.61}{100}) + 24 + 20 = 1290 \text{ ft Head}$$

1290 ft x 17 x 0.288 = 6320 HP

$$\frac{6320 \text{ HP} - 1500 \text{ HP/Dredge}}{1200 \text{ HP/Booster}} = 4 \text{ Boosters}$$

Dredge B to Site 26

$$\left(23{,}200 \times 1.25 \times \frac{5.61}{100}\right) + 24 + 20 = 1670 \text{ ft Head}$$

$$1670 \text{ ft} \times 17 \times 0.288 = 8180 \text{ HP}$$

$$\frac{8180 \text{ HP} - 1500 \text{ HP/Dredge}}{1200 \text{ HP/Booster}} = 6 \text{ Boosters}$$

Dredge C to Site 26

$$\left(13{,}700 \times 1.25 \times \frac{5.61}{100}\right) + 24 + 20 = 1000 \text{ ft Head}$$

$$1000 \text{ ft} \times 17 \times 0.288 = 4900 \text{ HP}$$

$$\frac{4900 \text{ HP} - 1500 \text{ HP/Dredge}}{1200 \text{ HP/Booster}} = 3 \text{ Boosters}$$

Dredge C to Site 27

$$\left(21{,}100 \times 1.25 \times \frac{5.61}{100}\right) + 24 + 255 = 1760 \text{ ft Head}$$

$$1760 \text{ ft} \times 17 \times 0.288 = 8610 \text{ HP}$$

$$\frac{8610 \text{ HP} - 1500 \text{ HP/Dredge}}{1200 \text{ HP/Booster}} = 6 \text{ Boosters}$$

Booster Operating Months

Dredge A	7 Boosters	4.58 mo
Dredge B	4 Boosters	3.12 mo
Dredge B	6 Boosters	1.46 mo
Dredge C	3 Boosters	1.42 mo
Dredge C	6 Boosters	3.16 mo
	76.52 Booster mo	

Booster Ownership Months

Dredge A	7 Boosters	4.58 mo
Dredge B	6 Boosters	4.58 mo
Dredge C	6 Boosters	4.58 mo
	87.02 Booster mo	

3) Area Required:

$$\frac{2.18 \times 10^6 \text{ cu yd}}{1613 \ \frac{\text{cu yd}}{\text{acre ft}} \ 10 \text{ ft}} = 135 \text{ Acres}$$

20% Fines	=	27
+ 5 Treatment	=	5
		167 Acres

COST CALCULATIONS:

I Mobilization:		
A. General		
3 Dredges @ \$100,000	300,000	
B. Laying Initial Lines		
128,100 ft @ \$4.50	575,000	
		875,000
II Dredging:		
A. Dredge Operating		
13.75 dredge mo @ (\$224,600+ \$1 (20,000))	3,369,000	
B. Dredge Ownership		
13.75 dredge mo @ \$40,000	550,000	
C. Booster Operating		
76.52 booster mo @ \$46,000	3,520,000	
D. Booster Ownership		
87.02 booster mo @ \$10,000	870,000	
E. Supervision & Engineering		
5.3 mo x 3 Dredges @ \$9,000	140,000	
F. Overhead & Profit		
@ 35%	2,957,000	
		11,407,000
III Pipeline Easement		
A. 128,100 ft @ \$ 575 / 1,000 ft		75,000
IV Diking & Wiers		
A. Diking		
Perimeter site 26 4800 ft		
Perimeter site 27 5400		
Perimeter site 29 9000		
19200 ft		
25% Cross Dikes 4800		
24000 ft 20 cu yd / ft @ \$6		
- \$107,000 Treatment Dikes	2,770,000	
B. Wiers		
2 Wiers / Site x 3 Sites @ \$12,000	70,000	
		2,840,000

V	Drift Boom		
	A. 500 $\frac{\text{ft}}{\text{Dredge}}$ x 3 Dredges @ \$20		30,000
VI	Clearing & Grubbing		
	A. 167 Acres 25% @ \$1,000		40,000
VII	Spoil Area Acquisition		
	A. 167 Acres @ \$2,000		330,000
VIII	Cover Material		
	A. 18 in Clay		
	167 Acres 43560 $\frac{\text{sq ft}}{\text{acre}}$ 1.5 ft $\frac{\text{cu yd}}{27 \text{ cu ft}}$ @ \$6		2,420,000
IX	Turf Establishment		
	A. 18 in Cover		
	167 Acres 43560 $\frac{\text{sq ft}}{\text{acre}}$ 1.5 ft $\frac{\text{cu yd}}{27 \text{ cu ft}}$ @ \$3		1,210,000
X	Seeding & Mulching		
	A. 167 Acres @ \$1,000		170,000
XI	PCB Testing & Dredge Control		
	A. PCB Testing		
	5.5 mi (5280 $\frac{\text{ft}}{\text{mi}}$) 845 ft @ $\frac{\$15}{100 \times 100 \text{ sq ft}}$	40,000	
	B. Dredge Control		
	13.75 dredge mo @ \$37,000	510,000	
			550,000
	Subtotal Without Treatment Costs		\$19,947,000
XII	Treatment by Sedimentation & Coagulation		
	A. 3 Dredges @ \$677,000		677,000
	Subtotal Including Treatment By Sedimentation & Coagulation		\$20,624,000
XIII	Contingencies @ 20%		4,125,000

XIV Engineering			1,031,000
XV Legal & Administrative			412,000
	Total Including Treatment By Sedimentation & Coagulation		$26,192,000
XIIB Treatment Including Filtration-Adsorption			
A. Sedimentation 3 Dredges @ $677,000		677,000	
B. Carbon Adsorption 38 MGD @ $10,250,000		10,250,000	
			10,927,000
	Subtotal Including Treatment with Filtration-Adsorption		$30,874,000
XIIIB Contingencies @ 20%			6,175,000
XIVB Engineering			1,544,000
XVB Legal & Administrative			618,000
	Total Including Treatment with Filtration-Adsorption		$39,211,000

COST ESTIMATE SUMMARY
REACH 1
FEDERAL DAM (RM 153.9) - LOCK 1 (RM 159.4)

	Volume of Bed Material (Mil. Cubic Yards)		2.18
	Disposal Site: 26 27 29		
I.	Mobilization		
	General 3 Dredges	300,000	
	Laying Initial Lines	575,000	
	Subtotal		875,000
II.	Dredging		
	Dredge Operating Cost	3,369,000	
	Dredge Ownership Cost	550,000	
	Booster Operating Cost	3,520,000	
	Booster Ownership Cost	870,000	
	Supervision and Eng.	140,000	
	Overhead and Profit @ 35%	2,957,000	
	Subtotal		11,407,000
III.	Pipeline Easement Costs		75,000
IV.	Diking and Weirs		2,840,000
V.	Drift Boom		30,000
VI.	Clearing and Grubbing		40,000
VII.	Site Acquisition		330,000
VIII.	Cover Material and Grading		2,420,000
IX.	Select Material for Turf Establishment		1,210,000
X.	Seeding and Mulching		170,000
XI.	PCB Testing		550,000
	Subtotal Without Treatment		$19,947,000
XII.	Effluent Treatment		
	Sedimentation & Coagulation		677,000
	Subtotal		$20,624,000
XIII.	Contingencies @ 20%		4,125,000
XIV.	Engineering		1,031,000
XV.	Legal & Administrative		412,000
	Total Cost Including Treatment By Sedimentation & Coagulation		$26,192,000

COST ESTIMATE SUMMARY
REACH 1 (Continued)

	Subtotal Without Treatment	$19,947,000
XIIB.	Effluent Treatment	
	Sedimentation & Coagulation	677,000
	Carbon Adsorption	10,250,000
	Subtotal	$30,874,000
XIIIB.	Contingencies @ 20%	6,175,000
XIVB.	Engineering	1,544,000
XVB.	Legal & Administrative	618,000
	Total Including Treatment with Filtration-Adsorption	$39,211,000

COST ESTIMATE SUMMARY
REACH 2
LOCK 1 (RM 159.4) - LOCK 2 (RM 163.4)

	Volume of Bed Material (Mil. Cubic Yards)		1.54
	Disposal Site: 33 34 36		
I.	Mobilization		
	General 2 Dredges	200,000	
	Laying Initial Lines	490,000	
	Subtotal		690,000
II.	Dredging		
	Dredge Operating Cost	2,559,000	
	Dredge Ownership Cost	389,000	
	Booster Operating Cost	4,882,000	
	Booster Ownership Cost	1,166,000	
	Supervision and Eng.	90,000	
	Overhead and Profit @ 35%	3,180,000	
	Subtotal		12,266,000
III.	Pipeline Easement Costs		65,000
IV.	Diking and Weirs		2,161,000
V.	Drift Boom		20,000
VI.	Clearing and Grubbing		30,000
VII.	Site Acquisition		238,000
VIII.	Cover Material and Grading		1,728,000
IX.	Select Material for Turf Establishment		864,000
X.	Seeding and Mulching		119,000
XI.	PCB Testing		393,000
	Subtotal Without Treatment		$18,574,000
XII.	Effluent Treatment		
	Sedimentation & Coagulation		540,000
	Subtotal		$19,114,000
XIII.	Contingencies @ 20%		3,823,000
XIV.	Engineering		956,000
XV.	Legal & Administrative		382,000
	Total Cost Including Treatment By Sedimentation & Coagulation		$24,275,000

COST ESTIMATE SUMMARY
REACH 2 (Continued)

	Subtotal Without Treatment	$18,574,000
XIIB.	Effluent Treatment	
	Sedimentation & Coagulation	540,000
	Carbon Adsorption	8,200,000
	Subtotal	$27,314,000
XIIIB.	Contingencies @ 20%	5,463,000
XIVB.	Engineering	1,366,000
XVB.	Legal & Administrative	546,000
	Total Including Treatment with Filtration-Adsorption	$34,689,000

COST ESTIMATE SUMMARY
REACH 3
LOCK 2 (RM 163.4) - LOCK 3 (RM 166.0)

	Volume of Bed Material (Mil. Cubic Yards)		1.22
	Disposal Site: 36 37 39		
I.	Mobilization		
	General 2 Dredges	200,000	
	Laying Initial Lines	516,000	
	Subtotal		716,000
II.	Dredging		
	Dredge Operating Cost	1,961,000	
	Dredge Ownership Cost	308,000	
	Booster Operating Cost	2,958,000	
	Booster Ownership Cost	616,000	
	Supervision and Eng.	72,000	
	Overhead and Profit @ 35%	2,070,000	
	Subtotal		7,985,000
III.	Pipeline Easement Costs		70,000
IV.	Diking and Weirs		1,789,000
V.	Drift Boom		20,000
VI.	Clearing and Grubbing		24,000
VII.	Site Acquisition		192,000
VIII.	Cover Material and Grading		1,393,000
IX.	Select Material for Turf Establishment		697,000
X.	Seeding and Mulching		96,000
XI.	PCB Testing		311,000
	Subtotal Without Treatment		$13,293,000
XII.	Effluent Treatment		
	Sedimentation & Coagulation		503,000
	Subtotal		$13,796,000
XIII.	Contingencies @20%		2,759,000
XIV.	Engineering		690,000
XV.	Legal & Administrative		276,000
	Total Cost Including Treatment By Sedimentation & Coagulation		$17,521,000

COST ESTIMATE SUMMARY
REACH 3 (Continued)

	Subtotal Without Treatment	$13,293,000
XIIB.	Effluent Treatment	
	Sedimentation & Coagulation	503,000
	Carbon Adsorption	8,200,000
	Subtotal	$21,996,000
XIIIB.	Contingencies @ 20%	4,399,000
XIVB.	Engineering	1,100,000
XVB.	Legal & Administrative	440,000
	Total Including Treatment with Filtration-Adsorption	$27,935,000

COST ESTIMATE SUMMARY
REACH 4
LOCK 3 (RM 166.0) - LOCK 4 (RM 168.2)

	Volume of Bed Material (Mil. Cubic Yards)		1.28
	Disposal Site: 23		
I.	Mobilization		
	General 2 Dredges	225,000	
	Laying Initial Lines	225,000	
	Subtotal		450,000
II.	Dredging		
	Dredge Operating Cost	1,990,000	
	Dredge Ownership Cost	320,000	
	Booster Operating Cost	1,860,000	
	Booster Ownership Cost	400,000	
	Supervision and Eng.	80,000	
	Overhead and Profit @ 35%	1,630,000	
	Subtotal		6,280,000
III.	Pipeline Easement Costs		30,000
IV.	Diking and Weirs		1,440,000
V.	Drift Boom		20,000
VI.	Clearing and Grubbing		30,000
VII.	Site Acquisition		230,000
VIII.	Cover Material and Grading		1,450,000
IX.	Select Material for Turf Establishment		730,000
X.	Seeding and Mulching		100,000
XI.	PCB Testing		320,000
	Subtotal Without Treatment		$11,080,000
XII.	Effluent Treatment		
	Sedimentation & Coagulation		503,000
	Subtotal		$11,583,000
XIII.	Contingencies @ 20%		2,317,000
XIV.	Engineering		579,000
XV.	Legal & Administrative		232,000
	Total Cost Including Treatment By Sedimentation & Coagulation		$14,711,000

COST ESTIMATE SUMMARY
REACH 4 (Continued)

	Subtotal Without Treatment	$11,080,000
XIIB.	Effluent Treatment	
	Sedimentation & Coagulation	503,000
	Carbon Adsorption	8,200,000
	Subtotal	$19,783,000
XIIIB.	Contingencies @ 20%	3,957,000
XIVB.	Engineering	989,000
XVB.	Legal & Administrative	396,000
	Total Including Treatment with Filtration-Adsorption	$25,125,000

COST ESTIATE SUMMARY
REACH 5
LOCK 4 (RM 168.2) - LOCK 5 (RM 183.4)

	Volume of Bed Material (Mil. Cubic Yards)		4.77
	Disposal Site: 17, 18, 19, 20, 21		
I.	Mobilization		
	General 6 Dredges	600,000	
	Laying Initial Lines	1,684,000	
	Subtotal		2,284,000
II.	Dredging		
	Dredge Operating Cost	8,406,000	
	Dredge Ownership Cost	1,205,000	
	Booster Operating Cost	20,621,000	
	Booster Ownership Cost	4,468,000	
	Supervision and Eng.	270,000	
	Overhead and Profit @ 35%	12,240,000	
	Subtotal		47,210,000
III.	Pipeline Easement Costs		215,000
IV.	Diking and Weirs		6,608,000
V.	Drift Boom		60,000
VI.	Clearing and Grubbing		90,000
VII.	Site Acquisition		720,000
VIII.	Cover Material and Grading		5,227,000
IX.	Select Material for Turf Establishment		2,613,000
X.	Seeding and Mulching		360,000
XI.	PCB Testing		1,208,000
	Subtotal Without Treatment		$66,595,000
XII.	Effluent Treatment		
	Sedimentation & Coagulation		1,201,000
	Subtotal		$67,796,000
XIII.	Contingencies @ 20%		13,559,000
XIV.	Engineering		3,390,000
XV.	Legal & Administrative		1,356,000
	Total Cost Including Treatment By Sedimentation & Coagulation		$86,101,000

COST ESTIMATE SUMMARY
REACH 5 (Continued)

	Subtotal Without Treatment	$66,595,000
XIIB.	Effluent Treatment	
	Sedimentation & Coagulation	1,201,000
	Carbon Adsorption	20,500,000
	Subtotal	$88,296,000
XIIIB.	Contingencies @ 20%	17,659,000
XIVB.	Engineering	4,415,000
XVB.	Legal & Administrative	1,766,000
	Total Including Treatment with Filtration-Adsorption	$112,136,000

COST ESTIMATE SUMMARY
REACH 6
LOCK 5 (RM 183.4) - LOCK 6 (RM 186.2)

	Volume of Bed Material (Mil. Cubic Yards)		0.94
	Disposal Site: 43		
I.	Mobilization		
	General 2 Dredges	200,000	
	Laying Initial Lines	103,000	
	Subtotal		303,000
II.	Dredging		
	Dredge Operating Cost	1,366,000	
	Dredge Ownership Cost	237,000	
	Booster Operating Cost	231,000	
	Booster Ownership Cost	59,000	
	Supervision and Eng.	54,000	
	Overhead and Profit @ 35%	681,000	
	Subtotal		2,628,000
III.	Pipeline Easement Costs		13,000
IV.	Diking and Weirs		712,000
V.	Drift Boom		20,000
VI.	Clearing and Grubbing		19,000
VII.	Site Acquisition		150,000
VIII.	Cover Material and Grading		1,089,000
IX.	Select Material for Turf Establishment		545,000
X.	Seeding and Mulching		75,000
XI.	PCB Testing		243,000
	Subtotal Without Treatment		$5,797,000
XII.	Effluent Treatment		
	Sedimentation & Coagulation		503,000
	Subtotal		$6,300,000
XIII.	Contingencies @ 20%		1,260,000
XIV.	Engineering		315,000
XV.	Legal & Administrative		126,000
	Total Cost Including Treatment By Sedimentation & Coagulation		$8,001,000

COST ESTIMATE SUMMARY
REACH 6 (Continued)

	Subtotal Without Treatment	$5,797,000
XIIB.	Effluent Treatment	
	Sedimentation & Coagulation	503,000
	Carbon Adsorption	8,200,000
	Subtotal	$14,500,000
XIIIB.	Contingencies @ 20%	2,900,000
XIVB.	Engineering	730,000
XVB.	Legal & Administrative	290,000
	Total Including Treatment with Filtration-Adsorption	$18,420,000

COST ESTIMATE SUMMARY
REACH 7
LOCK 6 (RM 186.2) - THOMPSON ISLAND DAM (RM 188.5)

	Volume of Bed Material (Mil. Cubic Yards)		0.86
	Disposal Site: 9		
I.	Mobilization *		
	General 2 Dredges	350,000	
	Laying Initial Lines	90,000	
	Subtotal		440,000
II.	Dredging		
	Dredge Operating Cost	1,250,000	
	Dredge Ownership Cost	220,000	
	Booster Operating Cost	370,000	
	Booster Ownership Cost	80,000	
	Supervision and Eng.	60,000	
	Overhead and Profit @ 35%	690,000	
	Subtotal		2,670,000
III.	Pipeline Easement Costs		10,000
IV.	Diking and Weirs		1,180,000
V.	Drift Boom		20,000
VI.	Clearing and Grubbing		20,000
VII.	Site Acquisition		140,000
VIII.	Cover Material and Grading		1,000,000
IX.	Select Material for Turf Establishment		500,000
X.	Seeding and Mulching		70,000
XI.	PCB Testing		220,000
	Subtotal Without Treatment		$6,270,000
XII.	Effluent Treatment		
	Sedimentation & Coagulation		503,000
	Subtotal		$6,773,000
XIII.	Contingencies @ 20%		1,354,000
XIV.	Engineering		339,000
XV.	Legal & Administrative		135,000
	Total Cost Including Treatment By Sedimentation & Coagulation		$8,601,000

COST ESTIMATE SUMMARY
REACH 7 (Continued)

	Subtotal Without Treatment	$6,270,000
XIIB.	Effluent Treatment	
	Sedimentation & Coagulation	503,000
	Carbon Adsorption	8,200,000
	Subtotal	$14,973,000
XIIIB.	Contingencies @ 20%	2,995,000
XIVB.	Engineering	749,000
XVB.	Legal & Administrative	299,000
	Total Including Treatment with Filtration-Adsorption	$19,016,000

* Includes allowances for access to and from land-locked Lock 6 pool

COST ESTIMATE SUMMARY
REACH 8
THOMPSON ISLAND DAM (RM 188.5) - LOCK 7 (RM 193.7)

	Volume of Bed Material (Mil. Cubic Yards)		1.72
	Disposal Site: 10		
I.	Mobilization		
	General 3 Dredges	300,000	
	Laying Initial Lines	220,000	
	Subtotal		520,000
II.	Dredging		
	Dredge Operating Cost	2,560,000	
	Dredge Ownership Cost	430,000	
	Booster Operating Cost	1,000,000	
	Booster Ownership Cost	220,000	
	Supervision and Eng.	110,000	
	Overhead and Profit @ 35%	1,510,000	
	Subtotal		5,830,000
III.	Pipeline Easement Costs		30,000
IV.	Diking and Weirs		1,820,000
V.	Drift Boom		30,000
VI.	Clearing and Grubbing		30,000
VII.	Site Acquisition		270,000
VIII.	Cover Material and Grading		1,930,000
IX.	Select Material for Turf Establishment		960,000
X.	Seeding and Mulching		130,000
XI.	PCB Testing		440,000
	Subtotal Without Treatment		$11,990,000
XII.	Effluent Treatment		
	Sedimentation & Coagulation		677,000
	Subtotal		$12,667,000
XIII.	Contingencies @ 20%		2,533,000
XIV.	Engineering		633,000
XV.	Legal & Administrative		253,000
	Total Cost Including Treatment By Sedimentation & Coagulation		$16,086,000

COST ESTIMATE SUMMARY
REACH 8 (Continued)

	Subtotal Without Treatment	$11,990,000
XIIB.	Effluent Treatment	
	Sedimentation & Coagulation	677,000
	Carbon Adsorption	10,250,000
	Subtotal	$22,917,000
XIIIB.	Contingencies @ 20%	4,583,000
XIVB.	Engineering	1,146,000
XVB.	Legal & Administrative	458,000
	Total Including Treatment with Filtration-Adsorption	$29,104,000

APPENDIX D

SAMPLE CALCULATION & COST ESTIMATES
ALTERNATIVE 2
COMPLETE REMOVAL
CLAMSHELL DREDGING - MECHANICAL UNLOADING
MULTIPLE DISPOSAL SITES

SAMPLE CALCULATION
REACH 1
FEDERAL DAM (RM 153.9) - LOCK 1 (RM 159.4)

REACH PARAMETERS:

Disposal Site No.	26, 29	
Volume of Material	2.18×10^6 cu yd	
Rehandling Areas	RM x 159.3	RM 160.1 (shared with Reach 2)
Maximum One-Way Tow	5.4 mi	6.2 mi
Average One-Way Tow	2.6 mi	3.4 mi
No. Locks to Pass	0	1
Trucking Distance	1.5 mi	1.5 mi
Perimeter Factor	0.0046 ft/cu yd	
Reach Length	5.5 mi	
Reach Width (Ave)	845 ft	

EQUIPMENT REQUIRED:

1) Clamshell Dredges
production rate = 120,000 cu yd/mo

$$\frac{2.18 \times 10^6 \text{ cy yd}}{120{,}000 \text{ cy yd/mo}} = 18.17 \text{ dredge months}$$

Using 4 Clamshell Dredges

$$\frac{18.17 \text{ dredge mo}}{4 \text{ dredges}} = 4.5 \text{ calendar mo}$$

2) Scows
travel time to rehandling area @ RM 159.3

Maximum round trip time

travel time	$2 \frac{(5.4) \text{ mi}}{4 \text{ knots}}$	2.7
tying up	@ 0.5 hr	0.5
passing locks	@ 0.5 hrs	0
		3.2 hr

Average round trip time

travel time	$\frac{2\ (2.6)}{4\ \text{knots}}$	1.3 hr
tying up	@ 0.5 hr	0.5
passing locks	@ 0.5 hr	0
		1.8 hr

Average time for RM 159.3 = $\frac{1.8 + 3.2}{2}$ = 2.5 hrs

Travel time for rehandling area @ RM 160.1

Maximum round trip time

travel time	$\frac{2\ (6.2)\ \text{mi}}{4\ \text{knots}}$	=	3.1
tying up	@ 0.5 hr	=	0.5
passing locks	@ 0.5 hr	=	0.5
			4.1 hrs

Average round trip time

travel time	$\frac{2\ (3.4)\ \text{mi}}{4\ \text{knots}}$	=	1.7
tying up	@ 0.5 hr	=	0.5
passing locks	@ 0.5 ht	=	0.5
			2.7 hrs

Average time for RM 160.1 = $\frac{4.1 + 2.7}{2}$ = 3.4 hrs

Loading scow time = $\frac{1000\ \text{cy yd scow}}{200\ \text{cy yd/hr}}$ = 5.0 hr

Unloading scow time = $\frac{1000\ \text{cu yd scow}}{312\ \text{cu yd/hr}}$ = 3.2 hr

Roundtrip time + unloading = loading

@ RM 159.3 2.5 + 3.2 > 5 hrs

@ RM 160.1 3.4 + 3.2 > 5 hrs

if total time 5-10 hrs use 3 scows/dredge

4 dredges x 3 scows/dredge = 12 scows

3) Tugs - Tenders

1 tug 1/moving scow

12 scows - 4 loading - 1 unloading = 7 tugs

1 tender/1 dredge = 4 tenders

4) Rehandling Units

production rate = 196,500 cu yd/mo

$$\frac{4 \text{ dredges} \times 120{,}000 \text{ cu yd/mo/dredge}}{196{,}500 \text{ cu yd/mo/unit}} = 2.5$$

use 3 units

5) Area Required

2.18×10^6 cu yd x 1.2 (swell factor) = 2.6×10^6 cu yd

$$\frac{2.6 \times 10^6 \text{ cu yd}}{1613 \ \frac{\text{cu yd}}{\text{acre ft}} \ 15 \text{ ft}} = 108 \text{ acres}$$

COST CALCULATIONS:

I Mobilization

A. Sum of pieces of equipment @ $17,650

4	dredges	
12	scows	
7	tugs	
4	tenders	
3	rehandling units	
1	hopper-conveyor barge	
31	pieces @ $17,650	550,000

II Dredging

A.	Clamshell Operating		
	18.17 dredge mo	@ $72,280	1,310,000
B.	Clamshell Ownership		
	18.17 dredge mo	@ $30,000	540,000
C.	Tugs - Tenders Operating		
	4.5 mo (7 tugs)	@ $43,309	
	4.5 mo (4 tenders)	@ $25,980	1,850,000
D.	Tugs - Tenders Ownership		
	4.5 mo (7 tugs)	@ $8,000	
	4.5 mo (4 tenders)	@ $4,000	330,000
E.	Scows Operating		
	4.5 mo 12 scows	@ $2,000	110,000
F.	Scows Ownership		
	4.5 mo 12 scows	@ $12,000	650,000
G.	Hopper Conveyor Barge Operating		
	4.5 mo	@ $22,962	100,000
H.	Hopper Conveyor Barge Ownership		
	4.5 mo	@ $15,000	70,000
I.	Rehandling Clamshell Operating		
	4.5 mo x 3 units	@ $27,500	370,000
J.	Rehandling Clamshell Ownership		
	4.5 mo x 3 units	@ $25,000	340,000
K.	Prepare Rehandling Area		
	2 rehandling areas		
	one is shared with Reach 2		
	(\$200,000 + $\frac{\$16,700}{\text{dredge}}$ 4 dredges) 1.5		400,000
L.	Loading, Hauling, Spreading		
	2.18×10^6 cu yd	@ $2.00	4,360,000

M.	Supervision & Engineering 5.2 mo x $\frac{\$9,000}{\text{dredge}}$ x 4 dredges	190,000	
N.	Overhead & Profit @ 35%	3,720,000	
			14,340,000
III	Diking A. Toe Dikes @ 4 cu yd/ft 2.18×10^6 cu yd 0.0046 $\frac{\text{ft}}{\text{cu yd}}$ x 4 $\frac{\text{cu yd}}{\text{ft}}$ @ \$6		240,000
IV	Drift Boom A. 500 $\frac{\text{ft}}{\text{dredge}}$ x 4 dredges @ \$20		40,000
V	Clearing & Grubbing A. 108 acres 25% @ \$1,000		30,000
VI	Site Acquisition A. 108 acres @ \$2,000		220,000
VII	Cover Material A. 18 in. Clay 108 acres 43,560 $\frac{\text{sq ft}}{\text{acre}}$ 1.5 $\frac{\text{ft cu yd}}{\text{27 cu ft}}$ @ \$6		1,570,000
VIII	Turf Establishment A. 18 in. Cover 108 acres 43,560 $\frac{\text{sq ft}}{\text{acre}}$ 1.5 $\frac{\text{ft cu yd}}{\text{27 cu ft}}$ @ \$3		780,000
IX	Seeding & Mulching A. 108 acres @ \$1,000		110,000

X	PCB Testing & Dredge Control	
	A. PCB Testing	
	5.5 mi $(5280 \frac{ft}{mi})$ 845 ft @ $\frac{\$15}{100 \times 100 \text{ sq ft}}$	
	B. Dredge Control	
	18.17 dredge mo @ \$37,500	
		720,000
	Subtotal Without Treatment Costs	\$18,600,000
XI	Treatment By Sedimentation & Coagulation	
	A. Sedimentation	
	2 treatment areas, one shared with Reach 2	
	\$220,000 x 1.5	300,000
	Subtotal Including Treatment By Sedimentation & Coagulation	\$18,900,000
XII	Contingencies @ 20%	3,780,000
XIII	Engineering	945,000
XIV	Legal & Administrative	378,000
	Total Including Treatment By Sedimentation & Coagulation	\$24,003,000

	Subtotal Without Treatment		18,600,000
XIB Treatment Including Filtration - Adsorption			
A. Sedimentation $220,000 x 1.5		300,000	
B. Carbon Adsorption 2 MGD @ $500,000		500,000	
			800,000
	Subtotal Including Treatment with Filtration-Adsorption		$19,400,000
XIIB Contingencies @ 20%			3,880,000
XIIB Engineering			970,000
XIVB Legal & Administrative			390,000
	Total Including Treatment with Filtration-Adsoption		$24,640,000

COST ESTIMATE SUMMARY
REACH 1
FEDERAL DAM (RM 153.9) - LOCK 1 (RM 159.4)

	Volume of Bed Material (Mil. Cubic Yards)		2.18
	Disposal Site: 29 26		
I.	Mobilization		550,000
II.	Dredging		
	Clamshells 4 4.5 months		
	Operating	1,310,000	
	Ownership	540,000	
	Tugs 7 Tenders 4		
	Operating	1,850,000	
	Ownership	330,000	
	Scows 12		
	Operating	110,000	
	Ownership	650,000	
	Hopper-Conveyor Barge		
	Operating	100,000	
	Ownership	70,000	
	Rehandling Clamshell 3		
	Operating	370,000	
	Ownership	340,000	
	Prepare Rehandling Area	400,000	
	Loading, Hauling, & Spreading	4,360,000	
	Supervision & Engineering	190,000	
	Overhead & Profit @ 35%	3,720,000	
	Subtotal		14,340,000
III.	Diking		240,000
IV.	Drift Boom		40,000
V.	Clearing & Grubbing		30,000
VI.	Site Acquisition		220,000
VII.	Cover Material		1,570,000
VIII.	Turf Establishment		780,000
IX.	Seeding & Mulching		110,000
X.	PCB Testing & Dredge Control		720,000
	Subtotal Without Treatment		$18,600,000
XI.	Treatment		
	Sedimentation & Coagulation		300,000
	Subtotal		$18,900,000
XII.	Contingencies @ 20%		3,780,000
XIII.	Engineering		945,000
XIV.	Legal & Administrative		378,000
	Total Including Treatment by Sedimentation & Coagulation		$24,003,000

COST ESTIMATE SUMMARY
REACH 1 (Continued)

	Subtotal Without Treatment	$18,600,000
XIB.	Treatment	
	Sedimentation & Coagulation	300,000
	Carbon Adsorption	500,000
	Subtotal	$19,400,000
XIIB.	Contingencies @ 20%	3,880,000
XIIIB.	Engineering	970,000
XIVB.	Legal & Administrative	390,000
	Total Including Treatment with Filtration-Adsorption	$24,640,000

COST ESTIMATE SUMMARY
REACH 2
LOCK 1 (RM 159.4) - LOCK 2 (RM 163.4)

	Volume of Bed Material (Mil. Cubic Yards)		1.54
	Disposal Site: 26 27		
I.	Mobilization		300,000
II.	Dredging		
	Clamshells 3 4.3 months		
	Operating	930,000	
	Ownership	380,000	
	Tugs 2 Tenders 3		
	Operating	700,000	
	Ownership	120,000	
	Scows 6		
	Operating	50,000	
	Ownership	310,000	
	Hopper-Conveyor Barge		
	Operating	100,000	
	Ownership	60,000	
	Rehandling Clamshell 2		
	Operating	240,000	
	Ownership	210,000	
	Prepare Rehandling Area	130,000	
	Loading, Hauling, & Spreading	3,080,000	
	Supervision & Engineering	130,000	
	Overhead & Profit @ 35%	2,260,000	
	Subtotal		8,700,000
III.	Diking		230,000
IV.	Drift Boom		30,000
V.	Clearing & Grubbing		20,000
VI.	Site Acquisition		150,000
VII.	Cover Material		1,110,000
VIII.	Turf Establishment		550,000
IX.	Seeding & Mulching		80,000
X.	PCB Testing & Dredge Control		510,000
	Subtotal Without Treatment		$11,680,000
XI.	Treatment		
	Sedimentation & Coagulation		100,000
	Subtotal		$11,780,000
XII.	Contingencies @ 20%		2,356,000
XIII.	Engineering		589,000
XIV.	Legal & Administrative		236,000
	Total Including Treatment by Sedimentation & Coagulation		$14,961,000

COST ESTIMATE SUMMARY
REACH 2 (Continued)

	Subtotal Without Treatment	$11,680,000
XIB.	Treatment	
	Sedimentation & Coagulation	100,000
	Carbon Adsorption	500,000
	Subtotal	$12,280,000
XIIB.	Contingencies @ 20%	2,456,000
XIIIB.	Engineering	614,000
XIVB.	Legal & Administrative	246,000
	Total Including Treatment with Filtration-Adsorption	$15,596,000

COST ESTIMATE SUMMARY
REACH 3
LOCK 2 (RM 163.4) - LOCK 3 (RM 166.0)

	Volume of Bed Material (Mil. Cubic Yards)		1.22
	Disposal Site: 36		
I.	Mobilization		280,000
II.	Dredging		
	Clamshells 2 5.1 months		
	Operating	730,000	
	Ownership	310,000	
	Tugs 3 Tenders 2		
	Operating	920,000	
	Ownership	160,000	
	Scows 6		
	Operating	60,000	
	Ownership	370,000	
	Hopper-Conveyor Barge		
	Operating	120,000	
	Ownership	80,000	
	Rehandling Clamshell 2		
	Operating	280,000	
	Ownership	250,000	
	Prepare Rehandling Area	120,000	
	Loading, Hauling, & Spreading	2,510,000	
	Supervision & Engineering	110,000	
	Overhead & Profit @ 35%	2,110,000	
	Subtotal		8,130,000
III.	Diking		160,000
IV.	Drift Boom		20,000
V.	Clearing & Grubbing		20,000
VI.	Site Acquisition		120,000
VII.	Cover Material		880,000
VIII.	Turf Establishment		440,000
IX.	Seeding & Mulching		60,000
X.	PCB Testing & Dredge Control		400,000
	Subtotal Without Treatment		$10,510,000
XI.	Treatment		
	Sedimentation & Coagulation		100,000
	Subtotal		$10,610,000
XII.	Contingencies @ 20%		2,122,000
XIII.	Engineering		531,000
XIV.	Legal & Administrative		212,000
	Total Including Treatment by Sedimentation & Coagulation		$13,475,000

COST ESTIMATE SUMMARY
REACH 3 (Continued)

	Subtotal Without Treatment	$10,510,000
XIB.	Treatment	
	Sedimentation & Coagulation	100,000
	Carbon Adsorption	500,000
	Subtotal	$11,110,000
XIIB.	Contingencies @ 20%	2,220,000
XIIIB.	Engineering	556,000
XIVB.	Legal & Administrative	222,000
	Total Including Treatment with Filtration-Adsorption	$14,108,000

COST ESTIMATE SUMMARY
REACH 4
LOCK 3 (RM 166.0) - LOCK 4 (RM 168.2)

	Volume of Bed Material (Mil. Cubic Yards)		1.28
	Disposal Site: 39		
I.	Mobilization		210,000
II.	Dredging		
	Clamshells 2 5.3 months		
	Operating	770,000	
	Ownership	320,000	
	Tugs 1 Tenders 2		
	Operating	510,000	
	Ownership	90,000	
	Scows 4		
	Operating	40,000	
	Ownership	260,000	
	Hopper-Conveyor Barge		
	Operating	120,000	
	Ownership	80,000	
	Rehandling Clamshell 2		
	Operating	290,000	
	Ownership	270,000	
	Prepare Rehandling Area	120,000	
	Loading, Hauling, & Spreading	2,820,000	
	Supervision & Engineering	110,000	
	Overhead & Profit @ 35%	2,030,000	
	Subtotal		7,830,000
III.	Diking		170,000
IV.	Drift Boom		20,000
V.	Clearing & Grubbing		20,000
VI.	Site Acquisition		130,000
VII.	Cover Material		920,000
VIII.	Turf Establishment		460,000
IX.	Seeding & Mulching		60,000
X.	PCB Testing & Dredge Control		420,000
	Subtotal Without Treatment		$10,240,000
XI.	Treatment		
	Sedimentation & Coagulation		100,000
	Subtotal		$10,340,000
XII.	Contingencies @ 20%		2,068,000
XIII.	Engineering		517,000
XIV.	Legal & Administrative		207,000
	Total Including Treatment by Sedimentation & Coagulation		$13,132,000

COST ESTIMATE SUMMARY
REACH 4 (Continued)

	Subtotal Without Treatment	$10,240,000
XIB.	Treatment	
	Sedimentation & Coagulation	100,000
	Carbon Adsorption	500,000
	Subtotal	$10,840,000
XIIB.	Contingencies @ 20%	2,168,000
XIIIB.	Engineering	542,000
XIVB.	Legal & Administrative	217,000
	Total Including Treatment with Filtration-Adsorption	$13,767,000

COST ESTIMATE SUMMARY
REACH 5
LOCK 4 (RM 168.2) - LOCK 5 (RM 183.4)

	Volume of Bed Material (Mil. Cubic Yards)		4.77
	Disposal Site: 18 19 20		
I.	Mobilization		1,360,000
II.	Dredging		
	Clamshells 8 5.0 months		
	Operating	2,870,000	
	Ownership	1,190,000	
	Tugs 23 Tenders 8		
	Operating	5,980,000	
	Ownership	1,070,000	
	Scows 32		
	Operating	320,000	
	Ownership	1,910,000	
	Hopper-Conveyor Barge		
	Operating	110,000	
	Ownership	70,000	
	Rehandling Clamshell 5		
	Operating	680,000	
	Ownership	620,000	
	Prepare Rehandling Area	330,000	
	Loading, Hauling, & Spreading	9,540,000	
	Supervision & Engineering	410,000	
	Overhead & Profit @ 35%	8,790,000	
	Subtotal		33,890,000
III.	Diking		620,000
IV.	Drift Boom		80,000
V.	Clearing & Grubbing		70,000
VI.	Site Acquisition		470,000
VII.	Cover Material		3,440,000
VIII.	Turf Establishment		1,720,000
IX.	Seeding & Mulching		240,000
X.	PCB Testing & Dredge Control		1,570,000
	Subtotal Without Treatment		$43,460,000
XI.	Treatment		
	Sedimentation & Coagulation		200,000
	Subtotal		$43,660,000
XII.	Contingencies @ 20%		8,732,000
XIII.	Engineering		2,183,000
XIV.	Legal & Administrative		873,000
	Total Including Treatment by Sedimentation & Coagulation		$55,448,000

COST ESTIMATE SUMMARY
REACH 5 (Continued)

	Subtotal Without Treatment	$43,460,000
XIB.	Treatment	
	Sedimentation & Coagulation	200,000
	Carbon Adsorption	500,000
	Subtotal	$44,160,000
XIIB.	Contingencies @ 20%	8,832,000
XIIIB.	Engineering	2,208,000
XIVB.	Legal & Administrative	883,000
	Total Including Treatment with Filtration-Adsorption	$56,083,000

COST ESTIMATE SUMMARY
REACH 6
LOCK 5 (RM 183.4) - LOCK 6 (RM 186.2)

	Volume of Bed Material (Mil. Cubic Yards)		0.94
	Disposal Site: 17		
I.	Mobilization		280,000
II.	Dredging		
	Clamshells 2 3.9 months		
	Operating	570,000	
	Ownership	240,000	
	Tugs 1 Tenders 2		
	Operating	370,000	
	Ownership	60,000	
	Scows 4		
	Operating	30,000	
	Ownership	190,000	
	Hopper-Conveyor Barge		
	Operating	90,000	
	Ownership	60,000	
	Rehandling Clamshell 2		
	Operating	220,000	
	Ownership	200,000	
	Prepare Rehandling Area	230,000	
	Loading, Hauling, & Spreading	1,880,000	
	Supervision & Engineering	80,000	
	Overhead & Profit @ 35%	1,480,000	
	Subtotal		5,700,000
III.	Diking		140,000
IV.	Drift Boom		20,000
V.	Clearing & Grubbing		10,000
VI.	Site Acquisition		90,000
VII.	Cover Material		680,000
VIII.	Turf Establishment		340,000
IX.	Seeding & Mulching		50,000
X.	PCB Testing & Dredge Control		310,000
	Subtotal Without Treatment		$7,620,000
XI.	Treatment		
	Sedimentation & Coagulation		200,000
	Subtotal		$7,820,000
XII.	Contingencies @ 20%		1,564,000
XIII.	Engineering		391,000
XIV.	Legal & Administrative		156,000
	Total Including Treatment by Sedimentation & Coagulation		$9,931,000

COST ESTIMATE SUMMARY
REACH 6 (Continued)

	Subtotal Without Treatment	$7,620,000
XIB.	Treatment	
	Sedimentation & Coagulation	200,000
	Carbon Adsorption	500,000
	Subtotal	$8,320,000
XIIB.	Contingencies @ 20%	1,664,000
XIIIB.	Engineering	416,000
XIVB.	Legal & Administrative	166,000
	Total Including Treatment with Filtration-Adsorption	$10,566,000

COST ESTIMATE SUMMARY
REACH 7
LOCK 6 (RM 186.2) - THOMPSON ISLAND DAM (RM 188.5)

	Volume of Bed Material (Mil. Cubic Yards)		0.86
	Disposal Site: 8		
I.	Mobilization *		370,000
II.	Dredging		
	Clamshells 1 7.2 months		
	Operating	520,000	
	Ownership	220,000	
	Tugs 1 Tenders 1		
	Operating	500,000	
	Ownership	90,000	
	Scows 2		
	Operating	30,000	
	Ownership	170,000	
	Hopper-Conveyor Barge		
	Operating	160,000	
	Ownership	110,000	
	Rehandling Clamshell 1		
	Operating	200,000	
	Ownership	180,000	
	Prepare Rehandling Area	220,000	
	Loading, Hauling, & Spreading	2,150,000	
	Supervision & Engineering	70,000	
	Overhead & Profit @ 35%	1,620,000	
	Subtotal		6,240,000
III.	Diking		130,000
IV.	Drift Boom		10,000
V.	Clearing & Grubbing		10,000
VI.	Site Acquisition		90,000
VII.	Cover Material		620,000
VIII.	Turf Establishment		310,000
IX.	Seeding & Mulching		40,000
X.	PCB Testing & Dredge Control		280,000
	Subtotal Without Treatment		$8,100,000
XI.	Treatment		
	Sedimentation & Coagulation		200,000
	Subtotal		$8,300,000
XII.	Contingencies @ 20%		1,660,000
XIII.	Engineering		415,000
XIV.	Legal & Administrative		166,000
	Total Including Treatment by Sedimentation & Coagulation		$10,541,000

COST ESTIMATE SUMMARY
REACH 7 (Continued)

	Subtotal Without Treatment	$8,100,000
XIB.	Treatment	
	Sedimentation & Coagulation	200,000
	Carbon Adsorption	500,000
	Subtotal	$8,800,000
XIIB.	Contingencies @ 20%	1,760,000
XIIIB.	Engineering	440,000
XIVB.	Legal & Administrative	176,000
	Total Including Treatment with Filtration-Adsorption	$11,176,000

* Includes allowance for access to and from land-locked Lock 6 pool.

COST ESTIMATE SUMMARY
REACH 8
THOMPSON ISLAND DAM (RM 188.5) - LOCK 7 (RM 193.7)

	Volume of Bed Material (Mil. Cubic Yards)		1.72
	Disposal Site: 12		
I.	Mobilization		300,000
II.	Dredging		
	Clamshells 3 4.8 months		
	Operating	1,040,000	
	Ownership	430,000	
	Tugs 2 Tenders 3		
	Operating	790,000	
	Ownership	130,000	
	Scows 6		
	Operating	60,000	
	Ownership	340,000	
	Hopper-Conveyor Barge		
	Operating	110,000	
	Ownership	70,000	
	Rehandling Clamshell 2		
	Operating	260,000	
	Ownership	240,000	
	Prepare Rehandling Area	250,000	
	Loading, Hauling, & Spreading	3,440,000	
	Supervision & Engineering	150,000	
	Overhead & Profit @ 35%	2,560,000	
	Subtotal		9,870,000
III.	Diking		180,000
IV.	Drift Boom		30,000
V.	Clearing & Grubbing		20,000
VI.	Site Acquisition		170,000
VII.	Cover Material		1,240,000
VIII.	Turf Establishment		620,000
IX.	Seeding & Mulching		90,000
X.	PCB Testing & Dredge Control		570,000
	Subtotal Without Treatment		$13,090,000
XI.	Treatment		
	Sedimentation & Coagulation		200,000
	Subtotal		$13,290,000
XII.	Contingencies @ 20%		2,658,000
XIII.	Engineering		665,000
XIV.	Legal & Administrative		266,000
	Total Including Treatment by Sedimentation & Coagulation		$16,879,000

COST ESTIMATE SUMMARY
REACH 8 (Continued)

	Subtotal Without Treatment	$13,090,000
XIB.	Treatment	
	Sedimentation & Coagulation	200,000
	Carbon Adsorption	500,000
	Subtotal	$13,790,000
XIIB.	Contingencies @ 20%	2,758,000
XIIIB.	Engineering	690,000
XIVB.	Legal & Administrative	276,000
	Total Including Treatment with Filtration-Adsorption	$17,514,000

APPENDIX E

SAMPLE CALCULATION & COST ESTIMATES
ALTERNATIVE 3
COMPLETE REMOVAL
CLAMSHELL DREDGING - MECHANICAL UNLOADING
SINGLE DISPOSAL AREA

SAMPLE CALCULATION
REACH 1
FEDERAL DAM (RM 153.9) - LOCK 1 (RM 159.4)

REACH PARAMETERS:

Disposal Site No.	11, 12
Volume of Material	2.18×10^6 cu yd
Rehandling Areas	RM 190.3
Maximum One-Way Tow	36.4 mi
Average One-Way Tow	33.6 mi
No. Locks to Pass	6
Trucking Distance	1.5 mi
Perimeter Factor	0.0023 ft/cu yd
Reach Length	5.5 mi
Reach Width (Ave)	845 ft

EQUIPMENT REQUIRED:

1) Clamshell Dredges

production rate = 120,000 cu yd/mo

$$\frac{2.18 \times 10^6 \text{ cy yd}}{120{,}000 \text{ cy yd/mo}} = 18.17 \text{ dredge months}$$

$$\frac{18.17 \text{ dredge mo}}{4 \text{ dredges}} = 4.5 \text{ calendar mo}$$

2) Scows

Maximum round trip time

travel time $\dfrac{2\,(36.4) \text{ mi}}{4 \text{ knots}}$	18.2 hr
tying up @ 0.5 hr	0.5 hr
passing locks @ 0.5 hrs	3.0 hr
	21.2 hrs

Average round trip time

travel time	$\frac{2\ (33.6)\ \text{mi}}{4\ \text{knots}}$	16.8 hr
tying up	@ 0.5 hr	0.5
passing locks	@ 0.5 hr	3.0
		20.3 hrs

$$\text{Average time for RM 190.3} = \frac{21.2 + 20.3}{2} = 20.8 \text{ hr}$$

$$\text{Loading time} = \frac{1000 \text{ cu yd scow}}{200 \text{ cy yd/hr}} = 5.0 \text{ hr}$$

$$\text{Unloading time} = \frac{1000 \text{ cy yd scow}}{312 \text{ cu yd/hr}} = 3.2 \text{ hr}$$

Round trip time + unloading time = loading time

20.8 + 3.2 = 24 hrs

0-5	hrs	use	2 scows/dredge
5-10	hrs	use	3 scows/dredge
10-15	hrs	use	4 scows/dredge
15-20	hrs	use	5 scows/dredge
20-25	hrs	use	6 scows/dredge

$$4 \text{ dredges} \times 6\ \frac{\text{scows}}{\text{dredge}} = 24 \text{ scows}$$

3) Tugs - Tenders

1 tug / moving scow

24 scows - 4 loading - 1 unloading = 19 tugs

1 tender/dredge

4 dredges x 1 tender/dredge = 4 tenders

4) Rehandling Units

production rate = 196,500 cu yd/mo

$$\frac{4 \text{ dredges} \times 120{,}000 \text{ cu yd/mo/dredge}}{196{,}500 \text{ cu yd/mo}} = 2.4$$

use 3 units

5) Area Required

2.18×10^6 cu yd x 1.2 (swell) = 2.6×10^6 cu yd

$$\frac{2.6 \times 10^6 \text{ cu yd}}{1613 \frac{\text{cu yd}}{\text{acre ft}} 15 \text{ ft}} = 108 \text{ acres}$$

COST CALCULATIONS:

I Mobilization

A. Sum of pieces of equipment @ $17,650

4 dredges		
24 scows		
19 tugs		
4 tenders		
3 rehandling units		
1 hopper-conveyor barge		
55 pieces @ $17,650		970,000

II Dredging

A. Clamshell Operating			
18.17 dredge mo	@ $72,280	1,310,000	
B. Clamshell Ownership			
18.17 dredge mo	@ $30,000	540,000	
C. Tugs - Tenders Operating			
4.5 mo (19 tugs)	@ $43,309		
4.5 mo (4 tenders)	@ $25,980	4,210,000	

D.	Tugs - Tenders Ownership 4.5 mo (19 tugs) @ \$8,000 4.5 mo (4 tenders) @ \$4,000	760,000	
E.	Scows Operating 4.5 mo (24 scows) @ \$2,000	220,000	
F.	Scows Ownership 4.5 mo (24 scows) @ \$12,000	1,310,000	
G.	Hopper Conveyor Barge Operating 4.5 mo @ \$22,962	100,000	
H.	Hopper Conveyor Barge Ownership 4.5 mo @ \$15,000	70,000	
I.	Rehandling Clamshells Operating 4.5 mo (3 units) @ \$27,500	370,000	
J.	Rehandling Clamshells Ownership 4.5 mo (3 units) @ \$25,000	340,000	
K.	Prepare Rehandling Area 1 rehandling area to be shared with 7 Reaches $(\$200{,}000 + \frac{\$16{,}700}{\text{dredge}} \times 4 \text{ dredges})\ \frac{1}{7}$	40,000	
L.	Loading, Hauling, Spreading 2.18×10^{6} cu yd @ \$2.00	4,360,000	
M.	Supervision & Engineering $5.2 \text{ mo} \times \frac{\$9{,}000}{\text{dredge}} \times 4 \text{ dredges}$	190,000	
N.	Overhead & Profit @ 35%	4,840,000	
			18,660,000

III	Diking		
	A.	Toe Dikes @ 4 cy/ft 2.18×10^6 cu yd x 0.0023 $\frac{\text{ft}}{\text{cu yd}}$ x 4 $\frac{\text{cu yd}}{\text{ft}}$ @ \$6	120,000
IV	Drift Boom		
	A.	500 $\frac{\text{ft}}{\text{dredge}}$ x 4 dredges @ \$20	40,000
V	Clearing & Grubbing		
	A.	108 acres 25% @ \$1,000	30,000
VI	Site Acquisition		
	A.	108 acres @ \$2,000	220,000
VII	Cover Material		
	A.	18 in. clay 108 acres 43,560 $\frac{\text{sq ft}}{\text{acre}}$ 1.5 ft $\frac{\text{cu yd}}{\text{27 cu ft}}$ @ \$6	1,570,000
VIII	Turf Establishment		
	A.	18 in. cover 108 acres 43,560 $\frac{\text{sq ft}}{\text{acre}}$ 1.5 ft $\frac{\text{cu yd}}{\text{27 cu ft}}$ @ \$3	780,000
IX	Seeding & Mulching		
	A.	108 acres @ \$1,000	110,000
X	PCB Testing & Dredge Control		
	A.	Testing 5.5 mi x (5280 $\frac{\text{ft}}{\text{mi}}$) x 845 ft @ $\frac{\$15}{100 \times 100 \text{ sq ft}}$	
	B.	Dredge Control 18.17 dredge mo @ \$37,500	
			720,000

	Subtotal Without Treatment Costs	$23,220,000
XI	Treatment By Sedimentation & Coagulation	
	A. Sedimentation treatment area is shared with 7 reachs $\frac{1}{7}$ ($220,000)	30,000
	Subtotal Including Treatment By Sedimentation & Coagulation	$23,250,000
XII	Contingencies @ 20%	4,650,000
XIII	Engineering	1,163,000
XIV	Legal & Administrative	465,000
	Total Including Treatment By Sedimentation & Coagulation	$29,528,000

XIB	Treatment Including Filtration - Adsorption		
	A. Sedimentation $\frac{1}{7}$ x $220,000	300,000	
	B. Carbon Adsorption 2 MGD @ $500,000	500,000	
			530,000
	Subtotal Including Treatment with Filtration - Adsorption		$23,750,000
XIIB	Contingencies @ 20%		4,750,000
XIIB	Engineering		1,188,000
XIVB	Legal & Administrative		475,000
	Total Including Treatment with Filtration - Adsoption		$30,163,000

COST ESTIMATE SUMMARY
REACH 1
FEDERAL DAM (RM 153.9) - LOCK 1 (RM 159.4)

	Volume of Bed Material (Mil. Cubic Yards)		2.18
I.	Mobilization		970,000
II.	Dredging		
	Clamshells 4 4.5 months		
	Operating	1,310,000	
	Ownership	540,000	
	Tugs 19 Tenders 4		
	Operating	4,210,000	
	Ownership	760,000	
	Scows 24		
	Operating	220,000	
	Ownership	1,310,000	
	Hopper-Conveyor Barge		
	Operating	100,000	
	Ownership	70,000	
	Rehandling Clamshell 3		
	Operating	370,000	
	Ownership	340,000	
	Prepare Rehandling Area	40,000	
	Loading, Hauling, & Spreading	4,360,000	
	Supervision & Engineering	190,000	
	Overhead & Profit @ 35%	4,840,000	
	Subtotal		18,660,000
III.	Diking		120,000
IV.	Drift Boom		40,000
V.	Clearing & Grubbing		30,000
VI.	Site Acquisition		220,000
VII.	Cover Material		1,570,000
VIII.	Turf Establishment		780,000
IX.	Seeding & Mulching		110,000
X.	PCB Testing & Dredge Control		720,000
	Subtotal Without Treatment		$23,220,000
XI.	Treatment		
	Sedimentation & Coagulation		30,000
	Subtotal		$23,250,000
XII.	Contingencies @ 20%		4,650,000
XIII.	Engineering		1,163,000
XIV.	Legal & Administrative		465,000
	Total Including Treatment by Sedimentation & Coagulation		$29,528,000

COST ESTIMATE SUMMARY
REACH 1 (Continued)

	Subtotal Without Treatment	$23,220,000
XIB.	Treatment	
	Sedimentation & Coagulation	30,000
	Carbon Adsorption	500,000
	Subtotal	$23,750,000
XIIB.	Contingencies @ 20%	4,750,000
XIIIB.	Engineering	1,188,000
XIVB.	Legal & Administrative	475,000
	Total Including Treatment with Filtration-Adsorption	$30,163,000

COST ESTIMATE SUMMARY
REACH 2
LOCK 1 (RM 159.4) - LOCK 2 (RM 163.4)

	Volume of Bed Material (Mil. Cubic Yards)		1.54
I.	Mobilization		720,000
II.	Dredging		
	Clamshells 3 4.3 months		
	Operating	930,000	
	Ownership	380,000	
	Tugs 14 Tenders 3		
	Operating	2,930,000	
	Ownership	530,000	
	Scows 18		
	Operating	150,000	
	Ownership	920,000	
	Hopper-Conveyor Barge		
	Operating	100,000	
	Ownership	60,000	
	Rehandling Clamshell 2		
	Operating	240,000	
	Ownership	210,000	
	Prepare Rehandling Area	40,000	
	Loading, Hauling, & Spreading	3,080,000	
	Supervision & Engineering	130,000	
	Overhead & Profit @ 35%	3,400,000	
	Subtotal		13,100,000
III.	Diking		90,000
IV.	Drift Boom		30,000
V.	Clearing & Grubbing		20,000
VI.	Site Acquisition		150,000
VII.	Cover Material		1,110,000
VIII.	Turf Establishment		550,000
IX.	Seeding & Mulching		80,000
X.	PCB Testing & Dredge Control		510,000
	Subtotal Without Treatment		$16,360,000
XI.	Treatment		
	Sedimentation & Coagulation		30,000
	Subtotal		$16,390,000
XII.	Contingencies @ 20%		3,278,000
XIII.	Engineering		820,000
XIV.	Legal & Administrative		328,000
	Total Including Treatment by Sedimentation & Coagulation		$20,816,000

COST ESTIMATE SUMMARY
REACH 2 (Continued)

	Subtotal Without Treatment	$16,360,000
XIB.	Treatment	
	Sedimentation & Coagulation	30,000
	Carbon Adsorption	500,000
	Subtotal	$16,890,000
XIIB.	Contingencies @ 20%	3,378,000
XIIIB.	Engineering	845,000
XIVB.	Legal & Administrative	338,000
	Total Including Treatment with Filtration-Adsorption	$21,451,000

COST ESTIMATE SUMMARY
REACH 3
LOCK 2 (RM 163.4) - LOCK 3 (RM 166.0)

	Volume of Bed Material (Mil. Cubic Yards)		1.22
I.	Mobilization		420,000
II.	Dredging		
	Clamshells 2 5.1 months		
	Operating	730,000	
	Ownership	310,000	
	Tugs 7 Tenders 2		
	Operating	1,810,000	
	Ownership	330,000	
	Scows 10		
	Operating	100,000	
	Ownership	610,000	
	Hopper-Conveyor Barge		
	Operating	120,000	
	Ownership	80,000	
	Rehandling Clamshell 2		
	Operating	280,000	
	Ownership	250,000	
	Prepare Rehandling Area	30,000	
	Loading, Hauling, & Spreading	2,440,000	
	Supervision & Engineering	110,000	
	Overhead & Profit @ 35%	2,520,000	
	Subtotal		9,720,000
III.	Diking		70,000
IV.	Drift Boom		20,000
V.	Clearing & Grubbing		20,000
VI.	Site Acquisition		120,000
VII.	Cover Material		880,000
VIII.	Turf Establishment		440,000
IX.	Seeding & Mulching		60,000
X.	PCB Testing & Dredge Control		400,000
	Subtotal Without Treatment		$12,150,000
XI.	Treatment		
	Sedimentation & Coagulation		30,000
	Subtotal		$12,180,000
XII.	Contingencies @ 20%		2,436,000
XIII.	Engineering		609,000
XIV.	Legal & Administrative		244,000
	Total Including Treatment by Sedimentation & Coagulation		$15,469,000

COST ESTIMATE SUMMARY
REACH 3 (Continued)

	Subtotal Without Treatment	$12,150,000
XIB.	Treatment	
	Sedimentation & Coagulation	30,000
	Carbon Adsorption	500,000
	Subtotal	$12,680,000
XIIB.	Contingencies @ 20%	2,536,000
XIIIB.	Engineering	634,000
XIVB.	Legal & Administrative	254,000
	Total Including Treatment with Filtration-Adsorption	$16,104,000

COST ESTIMATE SUMMARY
REACH 4
LOCK 3 (RM 166.0) - LOCK 4 (RM 168.2)

	Volume of Bed Material (Mil. Cubic Yards)		1.28
I.	Mobilization		420,000
II.	Dredging		
	Clamshells 2 5.3 months		
	Operating	770,000	
	Ownership	320,000	
	Tugs 7 Tenders 2		
	Operating	1,890,000	
	Ownership	340,000	
	Scows 10		
	Operating	110,000	
	Ownership	640,000	
	Hopper-Conveyor Barge		
	Operating	120,000	
	Ownership	80,000	
	Rehandling Clamshell 2		
	Operating	290,000	
	Ownership	270,000	
	Prepare Rehandling Area	30,000	
	Loading, Hauling, & Spreading	2,560,000	
	Supervision & Engineering	110,000	
	Overhead & Profit @ 35%	2,640,000	
	Subtotal		10,170,000
III.	Diking		70,000
IV.	Drift Boom		20,000
V.	Clearing & Grubbing		20,000
VI.	Site Acquisition		130,000
VII.	Cover Material		920,000
VIII.	Turf Establishment		460,000
IX.	Seeding & Mulching		60,000
X.	PCB Testing & Dredge Control		420,000
	Subtotal Without Treatment		$12,690,000
XI.	Treatment		
	Sedimentation & Coagulation		30,000
	Subtotal		$12,720,000
XII.	Contingencies @ 20%		2,544,000
XIII.	Engineering		636,000
XIV.	Legal & Administrative		254,000
	Total Including Treatment by Sedimentation & Coagulation		$16,154,000

COST ESTIMATE SUMMARY
REACH 4 (Continued)

	Subtotal Without Treatment	$12,690,000
XIB.	Treatment	
	Sedimentation & Coagulation	30,000
	Carbon Adsorption	500,000
	Subtotal	$13,220,000
XIIB.	Contingencies @ 20%	2,644,000
XIIIB.	Engineering	661,000
XIVB.	Legal & Administrative	264,000
	Total Including Treatment with Filtration-Adsorption	$16,789,000

COST ESTIMATE SUMMARY
REACH 5
LOCK 4 (RM 168.2) - LOCK 5 (RM 183.4)

	Volume of Bed Material (Mil. Cubic Yards)		4.77
I.	Mobilization		1,360,000
II.	Dredging		
	Clamshells 8 5.0 months		
	Operating	2,870,000	
	Ownership	1,190,000	
	Tugs 23 Tenders 8		
	Operating	5,980,000	
	Ownership	1,070,000	
	Scows 32		
	Operating	320,000	
	Ownership	1,910,000	
	Hopper-Conveyor Barge		
	Operating	110,000	
	Ownership	70,000	
	Rehandling Clamshell 5		
	Operating	680,000	
	Ownership	620,000	
	Prepare Rehandling Area	50,000	
	Loading, Hauling, & Spreading	9,540,000	
	Supervision & Engineering	410,000	
	Overhead & Profit @ 35%	8,690,000	
	Subtotal		33,510,000
III.	Diking		260,000
IV.	Drift Boom		80,000
V.	Clearing & Grubbing		70,000
VI.	Site Acquisition		470,000
VII.	Cover Material		3,440,000
VIII.	Turf Establishment		1,720,000
IX.	Seeding & Mulching		240,000
X.	PCB Testing & Dredge Control		1,570,000
	Subtotal Without Treatment		$42,750,000
XI.	Treatment		
	Sedimentation & Coagulation		30,000
	Subtotal		$42,750,000
XII.	Contingencies @ 20%		8,550,000
XIII.	Engineering		2,138,000
XIV.	Legal & Administrative		855,000
	Total Including Treatment by Sedimentation & Coagulation		$54,293,000

COST ESTIMATE SUMMARY
REACH 5 (Continued)

	Subtotal Without Treatment	$42,720,000
XIB.	Treatment	
	Sedimentation & Coagulation	30,000
	Carbon Adsorption	500,000
	Subtotal	$43,250,000
XIIB.	Contingencies @ 20%	8,650,000
XIIIB.	Engineering	2,163,000
XIVB.	Legal & Administrative	865,000
	Total Including Treatment with Filtration-Adsorption	$54,928,000

COST ESTIMATE SUMMARY
REACH 6
LOCK 5 (RM 183.4) - LOCK 6 (RM 186.2)

	Volume of Bed Material (Mil. Cubic Yards)		0.94
I.	Mobilization		280,000
II.	Dredging		
	Clamshells 2 3.9 months		
	Operating	570,000	
	Ownership	240,000	
	Tugs 3 Tenders 2		
	Operating	710,000	
	Ownership	130,000	
	Scows 6		
	Operating	50,000	
	Ownership	280,000	
	Hopper-Conveyor Barge		
	Operating	90,000	
	Ownership	60,000	
	Rehandling Clamshell 2		
	Operating	220,000	
	Ownership	200,000	
	Prepare Rehandling Area	30,000	
	Loading, Hauling, & Spreading	1,880,000	
	Supervision & Engineering	80,000	
	Overhead & Profit @ 35%	1,580,000	
	Subtotal		6,120,000
III.	Diking		50,000
IV.	Drift Boom		20,000
V.	Clearing & Grubbing		10,000
VI.	Site Acquisition		90,000
VII.	Cover Material		680,000
VIII.	Turf Establishment		340,000
IX.	Seeding & Mulching		50,000
X.	PCB Testing & Dredge Control		310,000
	Subtotal Without Treatment		$7,950,000
XI.	Treatment		
	Sedimentation & Coagulation		30,000
	Subtotal		$7,980,000
XII.	Contingencies @ 20%		1,596,000
XIII.	Engineering		399,000
XIV.	Legal & Administrative		160,000
	Total Including Treatment by Sedimentation & Coagulation		$10,135,000

COST ESTIMATE SUMMARY
REACH 6 (Continued)

	Subtotal Without Treatment	$7,950,000
XIB.	Treatment	
	Sedimentation & Coagulation	30,000
	Carbon Adsorption	500,000
	Subtotal	$8,480,000
XIIB.	Contingencies @ 20%	1,696,000
XIIIB.	Engineering	424,000
XIVB.	Legal & Administrative	170,000
	Total Including Treatment with Filtration-Adsorption	$10,770,000

COST ESTIMATE SUMMARY
REACH 7
LOCK 6 (RM 186.2) - THOMPSON ISLAND DAM (RM 188.5)

	Volume of Bed Material (Mil. Cubic Yards)		0.86
I.	Mobilization *		370,000
II.	Dredging		
	Clamshells 1 7.2 months		
	Operating	520,000	
	Ownership	220,000	
	Tugs 1 Tenders 1		
	Operating	500,000	
	Ownership	90,000	
	Scows 2		
	Operating	30,000	
	Ownership	170,000	
	Hopper-Conveyor Barge		
	Operating	160,000	
	Ownership	110,000	
	Rehandling Clamshell 1		
	Operating	200,000	
	Ownership	180,000	
	Prepare Rehandling Area	220,000	
	Loading, Hauling, & Spreading	2,150,000	
	Supervision & Engineering	70,000	
	Overhead & Profit @ 35%	1,620,000	
	Subtotal		6,240,000
III.	Diking		130,000
IV.	Drift Boom		10,000
V.	Clearing & Grubbing		10,000
VI.	Site Acquisition		90,000
VII.	Cover Material		620,000
VIII.	Turf Establishment		310,000
IX.	Seeding & Mulching		40,000
X.	PCB Testing & Dredge Control		280,000
	Subtotal Without Treatment		$8,100,000
XI.	Treatment		
	Sedimentation & Coagulation		200,000
	Subtotal		$8,300,000
XII.	Contingencies @ 20%		1,660,000
XIII.	Engineering		415,000
XIV.	Legal & Administrative		166,000
	Total Including Treatment by Sedimentation & Coagulation		$10,541,000

COST ESTIMATE SUMMARY
REACH 7 (Continued)

	Subtotal Without Treatment	$8,100,000
XIB.	Treatment	
	Sedimentation & Coagulation	200,000
	Carbon Adsorption	500,000
	Subtotal	$8,800,000
XIIB.	Contingencies @ 20%	1,760,000
XIIIB.	Engineering	440,000
XIVB.	Legal & Administrative	176,000
	Total Including Treatment with Filtration-Adsorption	$11,176,000

* Includes allowance for access to and from land-locked Lock 6 pool.

COST ESTIMATE SUMMARY
REACH 8
THOMPSON ISLAND DAM (RM 188.5) - LOCK 7 (RM 193.7)

	Volume of Bed Material (Mil. Cubic Yards)		1.72
I.	Mobilization		300,000
II.	Dredging		
	Clamshells 3 4.8 months		
	Operating	1,040,000	
	Ownership	430,000	
	Tugs 2 Tenders 3		
	Operating	790,000	
	Ownership	130,000	
	Scows 6		
	Operating	60,000	
	Ownership	340,000	
	Hopper-Conveyor Barge		
	Operating	110,000	
	Ownership	70,000	
	Rehandling Clamshell 2		
	Operating	260,000	
	Ownership	240,000	
	Prepare Rehandling Area	40,000	
	Loading, Hauling, & Spreading	3,440,000	
	Supervision & Engineering	150,000	
	Overhead & Profit @ 35%	2,480,000	
	Subtotal		9,580,000
III.	Diking		90,000
IV.	Drift Boom		30,000
V.	Clearing & Grubbing		20,000
VI.	Site Acquisition		170,000
VII.	Cover Material		1,240,000
VIII.	Turf Establishment		620,000
IX.	Seeding & Mulching		90,000
X.	PCB Testing & Dredge Control		570,000
	Subtotal Without Treatment		$12,710,000
XI.	Treatment		
	Sedimentation & Coagulation		30,000
	Subtotal		$12,740,000
XII.	Contingencies @ 20%		2,548,000
XIII.	Engineering		637,000
XIV.	Legal & Administrative		255,000
	Total Including Treatment by Sedimentation & Coagulation		$16,180,000

COST ESTIMATE SUMMARY
REACH 8 (Continued)

	Subtotal Without Treatment	$12,710,000
XIB.	Treatment	
	Sedimentation & Coagulation	30,000
	Carbon Adsorption	500,000
	Subtotal	$13,240,000
XIIB.	Contingencies @ 20%	2,648,000
XIIIB.	Engineering	662,000
XIVB.	Legal & Administrative	265,000
	Total Including Treatment with Filtration-Adsorption	$16,815,000

APPENDIX F

SAMPLE CALCULATION & COST ESTIMATES
ALTERNATIVE 3A
COMPLETE REMOVAL
CLAMSHELL DREDGING - MECHANICAL UNLOADING
SINGLE DISPOSAL AREA
WITH CONVEYOR OPTION

SAMPLE CALCULATION
REACH 1
FEDERAL DAM (RM 153.9) - LOCK 1 (RM 159.4)

REACH PARAMETERS:

Disposal Site No.	11, 12
Volume of Material	2.18×10^6 cu yd
Rehandling Areas	RM 190.3
Maximum One-Way Tow	36.4 mi
Average One-Way Tow	33.6 mi
No. Locks to Pass	6
Trucking Distance	1.5 mi
Perimeter Factor	0.0023 ft/cu yd
Reach Length	5.5 mi
Reach Width (Ave)	845 ft

EQUIPMENT REQUIRED:

Same as Clamshell - Excavation
Mechanical Unloading
Single Disposal Sits

COST CALCULATIONS:

Same as Clamshell - Excavation
Mechanical Unloading
Single Disposal Site

Except for Loading, Hauling &
Spreading cost

I	Mobilization		970,000
II	Dredging		
	A. Clamshell Operating	1,310,000	
	B. Clamshell Ownership	540,000	
	C. Tugs - Tenders Operating	4,210,000	
	D. Tugs - Tenders Ownership	760,000	

E.	Scows Operating	220,000	
F.	Scows Ownership	1,310,000	
G.	Hopper - Conveyor Barge Operating	100,000	
H.	Hopper - Conveyor Barge Ownership	70,000	
I.	Rehandling Units Operating	370,000	
J.	Rehandling Units Ownership	340,000	
K.	Prepare Rehandling Area	40,000	
L.	Loading, Hauling & Spreading 2.18×10^6 cu yd @ \$1.20	2,620,000	
M.	Supervision & Engineering	190,000	
N.	Overhead & Profit @ 35%	4,230,000	
			16,310,000
III	Diking		120,000
IV	Drift Boom		40,000
V	Clearing & Grubbing		30,000
VI	Site Acquisition		220,000
VII	Cover Material		1,570,000
VIII	Turf Establishment		780,000
IX	Seeding & Mulching		110,000
X	PCB Testing & Dredge Control		720,000

		Subtotal Without Treatment Costs	$20,870,000
XI	Treatment By Sedimentation & Coagulation		
	A. Sedimentation		30,000
		Subtotal Including Treatment By Sedimentation & Coagulation	$20,900,000
XII	Contingencies @ 20%		4,180,000
XIII	Engineering		1,050,000
XIV	Legal & Administrative		420,000
		Total Including Treatment By Sedimentation & Coagulation	$26,550,000
XIB	Treatment Including Filtration - Adsorption		
	A. Sedimentation		30,000
	B. Carbon Adsorption		500,000
		Subtotal Including Treatment with Filtration - Adsorption	$21,400,000
XIIB	Contingencies @ 20%		4,280,000
XIIB	Engineering		1,070,000
XIVB	Legal & Administrative		430,000
		Total Including Treatment with Filtration - Adsoption	$27,180,000

COST ESTIMATE SUMMARY
REACH 1
FEDERAL DAM (RM 153.9) - LOCK 1 (RM 159.4)

	Volume of Bed Material (Mil. Cubic Yards)		2.18
I.	Mobilization		970,000
II.	Dredging		
	Clamshells 4 4.5 months		
	Operating	1,310,000	
	Ownership	540,000	
	Tugs 19 Tenders 4		
	Operating	4,210,000	
	Ownership	760,000	
	Scows 24		
	Operating	220,000	
	Ownership	1,310,000	
	Hopper-Conveyor Barge		
	Operating	100,000	
	Ownership	70,000	
	Rehandling Clamshell 3		
	Operating	370,000	
	Ownership	340,000	
	Prepare Rehandling Area	40,000	
	Loading, Hauling, & Spreading	2,620,000	
	Supervision & Engineering	190,000	
	Overhead & Profit @ 35%	4,230,000	
	Subtotal		16,310,000
III.	Diking		120,000
IV.	Drift Boom		40,000
V.	Clearing & Grubbing		30,000
VI.	Site Acquisition		220,000
VII.	Cover Material		1,570,000
VIII.	Turf Establishment		780,000
IX.	Seeding & Mulching		110,000
X.	PCB Testing & Dredge Control		720,000
	Subtotal Without Treatment		$20,870,000
XI.	Treatment		
	Sedimentation & Coagulation		30,000
	Subtotal		$20,900,000
XII.	Contingencies @ 20%		4,180,000
XIII.	Engineering		1,050,000
XIV.	Legal & Administrative		420,000
	Total Including Treatment by Sedimentation & Coagulation		$26,550,000

COST ESTIMATE SUMMARY
REACH 1 (Continued)

	Subtotal Without Treatment	$20,870,000
XIB.	Treatment	
	Sedimentation & Coagulation	30,000
	Carbon Adsorption	500,000
	Subtotal	$21,400,000
XIIB.	Contingencies @ 20%	4,280,000
XIIIB.	Engineering	1,070,000
XIVB.	Legal & Administrative	430,000
	Total Including Treatment with Filtration - Adsorption	$27,180,000

COST ESTIMATE SUMMARY
REACH 2
LOCK 1 (RM 159.4) - LOCK 2 (RM 163.4)

	Volume of Bed Material (Mil. Cubic Yards)		1.54
I.	Mobilization		720,000
II.	Dredging		
	Clamshells 3 4.3 months		
	Operating	930,000	
	Ownership	380,000	
	Tugs 14 Tenders 3		
	Operating	2,930,000	
	Ownership	530,000	
	Scows 18		
	Operating	150,000	
	Ownership	920,000	
	Hopper-Conveyor Barge		
	Operating	100,000	
	Ownership	60,000	
	Rehandling Clamshell 2		
	Operating	240,000	
	Ownership	210,000	
	Prepare Rehandling Area	40,000	
	Loading, Hauling, & Spreading	1,850,000	
	Supervision & Engineering	130,000	
	Overhead & Profit @ 35%	2,960,000	
	Subtotal		11,430,000
III.	Diking		90,000
IV.	Drift Boom		30,000
V.	Clearing & Grubbing		20,000
VI.	Site Acquisition		150,000
VII.	Cover Material		1,110,000
VIII.	Turf Establishment		550,000
IX.	Seeding & Mulching		80,000
X.	PCB Testing & Dredge Control		510,000
	Subtotal Without Treatment		$14,690,000
XI.	Treatment		
	Sedimentation & Coagulation		30,000
	Subtotal		$14,720,000
XII.	Contingencies @ 20%		2,940,000
XIII.	Engineering		740,000
XIV.	Legal & Administrative		290,000
	Total Including Treatment by Sedimentation & Coagulation		$18,690,000

COST ESTIMATE SUMMARY
REACH 2 (Continued)

	Subtotal Without Treatment	$14,690,000
XIB.	Treatment	
	Sedimentation & Coagulation	30,000
	Carbon Adsorption	500,000
	Subtotal	$15,220,000
XIIB.	Contingencies @ 20%	3,040,000
XIIIB.	Engineering	760,000
XIVB.	Legal & Administrative	300,000
	Total Including Treatment with Filtration - Adsorption	$19,320,000

COST ESTIMATE SUMMARY
REACH 3
LOCK 2 (RM 163.4) - LOCK 3 (RM 166.0)

	Volume of Bed Material (Mil. Cubic Yards)		1.22
I.	Mobilization		420,000
II.	Dredging		
	Clamshells 2 5.1 months		
	Operating	730,000	
	Ownership	310,000	
	Tugs 7 Tenders 2		
	Operating	1,810,000	
	Ownership	330,000	
	Scows 10		
	Operating	100,000	
	Ownership	610,000	
	Hopper-Conveyor Barge		
	Operating	120,000	
	Ownership	80,000	
	Rehandling Clamshell 2		
	Operating	280,000	
	Ownership	250,000	
	Prepare Rehandling Area	30,000	
	Loading, Hauling, & Spreading	1,460,000	
	Supervision & Engineering	110,000	
	Overhead & Profit @ 35%	2,180,000	
	Subtotal		8,400,000
III.	Diking		70,000
IV.	Drift Boom		20,000
V.	Clearing & Grubbing		20,000
VI.	Site Acquisition		120,000
VII.	Cover Material		880,000
VIII.	Turf Establishment		440,000
IX.	Seeding & Mulching		60,000
X.	PCB Testing & Dredge Control		400,000
	Subtotal Without Treatment		$10,830,000
XI.	Treatment		
	Sedimentation & Coagulation		30,000
	Subtotal		$10,860,000
XII.	Contingencies @ 20%		2,170,000
XIII.	Engineering		540,000
XIV.	Legal & Administrative		220,000
	Total Including Treatment by Sedimentation & Coagulation		$13,790,000

COST ESTIMATE SUMMARY
REACH 3 (Continued)

	Subtotal Without Treatment	$10,830,000
XIB.	Treatment	
	Sedimentation & Coagulation	30,000
	Carbon Adsorption	500,000
	Subtotal	$11,360,000
XIIB.	Contingencies @ 20%	2,270,000
XIIIB.	Engineering	570,000
XIVB.	Legal & Administrative	230,000
	Total Including Treatment with Filtration - Adsorption	$14,430,000

COST ESTIMATE SUMMARY
REACH 4
LOCK 3 (RM 166.0) - LOCK 4 (RM 168.2)

	Volume of Bed Material (Mil. Cubic Yards)		1.28
I.	Mobilization		420,000
II.	Dredging		
	Clamshells 2 5.3 months		
	Operating	770,000	
	Ownership	320,000	
	Tugs 7 Tenders 2		
	Operating	1,890,000	
	Ownership	340,000	
	Scows 10		
	Operating	110,000	
	Ownership	640,000	
	Hopper-Conveyor Barge		
	Operating	120,000	
	Ownership	80,000	
	Rehandling Clamshell 2		
	Operating	290,000	
	Ownership	270,000	
	Prepare Rehandling Area	30,000	
	Loading, Hauling, & Spreading	1,540,000	
	Supervision & Engineering	110,000	
	Overhead & Profit @ 35%	2,280,000	
	Subtotal		8,790,000
III.	Diking		70,000
IV.	Drift Boom		20,000
V.	Clearing & Grubbing		20,000
VI.	Site Acquisition		130,000
VII.	Cover Material		920,000
VIII.	Turf Establishment		460,000
IX.	Seeding & Mulching		60,000
X.	PCB Testing & Dredge Control		420,000
	Subtotal Without Treatment		$11,310,000
XI.	Treatment		
	Sedimentation & Coagulation		30,000
	Subtotal		$11,340,000
XII.	Contingencies @ 20%		2,270,000
XIII.	Engineering		570,000
XIV.	Legal & Administrative		230,000
	Total Including Treatment by Sedimentation & Coagulation		$14,410,000

COST ESTIMATE SUMMARY
REACH 4 (Continued)

	Subtotal Without Treatment	$11,310,000
XIB.	Treatment	
	Sedimentation & Coagulation	30,000
	Carbon Adsorption	500,000
	Subtotal	$11,840,000
XIIB.	Contingencies @ 20%	2,370,000
XIIIB.	Engineering	590,000
XIVB.	Legal & Administrative	240,000
	Total Including Treatment with Filtration - Adsorption	$15,040,000

COST ESTIMATE SUMMARY
REACH 5
LOCK 4 (RM 168.2) - LOCK 5 (RM 183.4)

	Volume of Bed Material (Mil. Cubic Yards)		4.77
I.	Mobilization		1,360,000
II.	Dredging		
	Clamshells 8 5.0 months		
	Operating	2,870,000	
	Ownership	1,190,000	
	Tugs 23 Tenders 8		
	Operating	5,980,000	
	Ownership	1,070,000	
	Scows 32		
	Operating	320,000	
	Ownership	1,910,000	
	Hopper-Conveyor Barge		
	Operating	110,000	
	Ownership	70,000	
	Rehandling Clamshell 5		
	Operating	680,000	
	Ownership	620,000	
	Prepare Rehandling Area	50,000	
	Loading, Hauling, & Spreading	5,720,000	
	Supervision & Engineering	410,000	
	Overhead & Profit @ 35%	7,350,000	
	Subtotal		28,350,000
III.	Diking		260,000
IV.	Drift Boom		80,000
V.	Clearing & Grubbing		70,000
VI.	Site Acquisition		470,000
VII.	Cover Material		3,440,000
VIII.	Turf Establishment		1,720,000
IX.	Seeding & Mulching		240,000
X.	PCB Testing & Dredge Control		1,570,000
	Subtotal Without Treatment		$37,560,000
XI.	Treatment		
	Sedimentation & Coagulation		30,000
	Subtotal		$37,590,000
XII.	Contingencies @ 20%		7,520,000
XIII.	Engineering		1,880,000
XIV.	Legal & Administrative		750,000
	Total Including Treatment by Sedimentation & Coagulation		$47,740,000

COST ESTIMATE SUMMARY
REACH 5 (Continued)

	Subtotal Without Treatment	$37,560,000
XIB.	Treatment	
	Sedimentation & Coagulation	30,000
	Carbon Adsorption	500,000
	Subtotal	$38,090,000
XIIB.	Contingencies @ 20%	7,620,000
XIIIB.	Engineering	1,900,000
XIVB.	Legal & Administrative	760,000
	Total Including Treatment with Filtration - Adsorption	$48,370,000

COST ESTIMATE SUMMARY
REACH 6
LOCK 5 (RM 183.4) - LOCK 6 (RM 186.2)

	Volume of Bed Material (Mil. Cubic Yards)		0.94
I.	Mobilization		280,000
II.	Dredging		
	Clamshells 2 3.9 months		
	Operating	570,000	
	Ownership	240,000	
	Tugs 3 Tenders 2		
	Operating	710,000	
	Ownership	130,000	
	Scows 6		
	Operating	50,000	
	Ownership	280,000	
	Hopper-Conveyor Barge		
	Operating	90,000	
	Ownership	60,000	
	Rehandling Clamshell 2		
	Operating	220,000	
	Ownership	200,000	
	Prepare Rehandling Area	30,000	
	Loading, Hauling, & Spreading	1,130,000	
	Supervision & Engineering	80,000	
	Overhead & Profit @ 35%	1,330,000	
	Subtotal		5,120,000
III.	Diking		50,000
IV.	Drift Boom		20,000
V.	Clearing & Grubbing		10,000
VI.	Site Acquisition		90,000
VII.	Cover Material		680,000
VIII.	Turf Establishment		340,000
IX.	Seeding & Mulching		50,000
X.	PCB Testing & Dredge Control		310,000
	Subtotal Without Treatment		$6,950,000
XI.	Treatment		
	Sedimentation & Coagulation		30,000
	Subtotal		$6,980,000
XII.	Contingencies @ 20%		1,400,000
XIII.	Engineering		350,000
XIV.	Legal & Administrative		140,000
	Total Including Treatment by Sedimentation & Coagulation		$8,870,000

COST ESTIMATE SUMMARY
REACH 6 (Continued)

	Subtotal Without Treatment	$6,950,000
XIB.	Treatment	
	Sedimentation & Coagulation	30,000
	Carbon Adsorption	500,000
	Subtotal	$7,480,000
XIIB.	Contingencies @ 20%	1,500,000
XIIIB.	Engineering	370,000
XIVB.	Legal & Administrative	150,000
	Total Including Treatment with Filtration - Adsorption	$9,500,000

COST ESTIMATE SUMMARY
REACH 7
LOCK 6 (RM 186.2) - THOMPSON ISLAND DAM (RM 188.5)

	Volume of Bed Material (Mil. Cubic Yards)		0.86
I.	Mobilization *		370,000
II.	Dredging		
	Clamshells 1 7.2 months		
	Operating	520,000	
	Ownership	220,000	
	Tugs 1 Tenders 1		
	Operating	500,000	
	Ownership	90,000	
	Scows 2		
	Operating	30,000	
	Ownership	170,000	
	Hopper-Conveyor Barge		
	Operating	160,000	
	Ownership	110,000	
	Rehandling Clamshell 1		
	Operating	200,000	
	Ownership	180,000	
	Prepare Rehandling Area	220,000	
	Loading, Hauling, & Spreading	2,880,000	
	Supervision & Engineering	70,000	
	Overhead & Profit @ 35%	1,850,000	
	Subtotal		7,200,000
III.	Diking		130,000
IV.	Drift Boom		10,000
V.	Clearing & Grubbing		10,000
VI.	Site Acquisition		90,000
VII.	Cover Material		620,000
VIII.	Turf Establishment		310,000
IX.	Seeding & Mulching		40,000
X.	PCB Testing & Dredge Control		280,000
	Subtotal Without Treatment		$9,060,000
XI.	Treatment		
	Sedimentation & Coagulation		200,000
	Subtotal		$9,260,000
XII.	Contingencies @ 20%		1,850,000
XIII.	Engineering		460,000
XIV.	Legal & Administrative		190,000
	Total Includig Treatment by Sedimentation & Coagulation		$11,760,000

COST ESTIMATE SUMMARY
REACH 7 (Continued)

	Subtotal Without Treatment	$9,060,000
XIB.	Treatment	
	Sedimentation & Coagulation	200,000
	Carbon Adsorption	500,000
	Subtotal	$9,760,000
XIIB.	Contingencies @ 20%	1,950,000
XIIIB.	Engineering	490,000
XIVB.	Legal & Administrative	200,000
	Total Including Treatment with Filtration - Adsorption	$12,400,000

* Includes allowance for access to and from land-locked Lock 6 pool.

COST ESTIMATE SUMMARY
REACH 8
THOMPSON ISLAND DAM (RM 188.5) - LOCK 7 (RM 193.7)

	Volume of Bed Material (Mil. Cubic Yards)		1.72
I.	Mobilization		300,000
II.	Dredging		
	Clamshells 3 4.8 months		
	Operating	1,040,000	
	Ownership	430,000	
	Tugs 2 Tenders 3		
	Operating	790,000	
	Ownership	130,000	
	Scows 6		
	Operating	60,000	
	Ownership	340,000	
	Hopper-Conveyor Barge		
	Operating	110,000	
	Ownership	70,000	
	Rehandling Clamshell 2		
	Operating	260,000	
	Ownership	240,000	
	Prepare Rehandling Area	40,000	
	Loading, Hauling, & Spreading	2,060,000	
	Supervision & Engineering	150,000	
	Overhead & Profit @ 35%	2,000,000	
	Subtotal		7,720,000
III.	Diking		90,000
IV.	Drift Boom		30,000
V.	Clearing & Grubbing		20,000
VI.	Site Acquisition		170,000
VII.	Cover Material		1,240,000
VIII.	Turf Establishment		620,000
IX.	Seeding & Mulching		90,000
X.	PCB Testing & Dredge Control		570,000
	Subtotal Without Treatment		$10,850,000
XI.	Treatment		
	Sedimentation & Coagulation		30,000
	Subtotal		$10,880,000
XII.	Contingencies @ 20%		2,180,000
XIII.	Engineering		540,000
XIV.	Legal & Administrative		220,000
	Total Including Treatment by Sedimentation & Coagulation		$13,820,000

COST ESTIMATE SUMMARY
REACH 8 (Continued)

	Subtotal Without Treatment	$10,850,000
XIB.	Treatment	
	Sedimentation & Coagulation	30,000
	Carbon Adsorption	500,000
	Subtotal	$11,380,000
XIIB.	Contingencies @ 20%	2,280,000
XIIIB.	Engineering	570,000
XIVB.	Legal & Administrative	230,000
	Total Including Treatment with Filtration - Adsorption	$14,460,000

APPENDIX G

COST ESTIMATES
PARTIAL REMOVAL
CLAMSHELL DREDGING - MECHANICAL UNLOADING
SINGLE DISPOSAL AREA

COST ESTIMATE SUMMARY
REACH 6
LOCK 5 (RM 183.4) - LOCK 6 (RM 186.2)

	Volume of Bed Material (Mil. Cubic Yards)		0.49
I.	Mobilization		140,000
II.	Dredging		
	Clamshells 1 4.1 months		
	Operating	300,000	
	Ownership	120,000	
	Tugs 1 Tenders 1		
	Operating	280,000	
	Ownership	50,000	
	Scows 3		
	Operating	20,000	
	Ownership	150,000	
	Hopper-Conveyor Barge		
	Operating	90,000	
	Ownership	60,000	
	Rehandling Clamshell 1		
	Operating	110,000	
	Ownership	100,000	
	Prepare Rehandling Area	110,000	
	Loading, Hauling, & Spreading	980,000	
	Supervision & Engineering	40,000	
	Overhead & Profit @ 35%	840,000	
	Subtotal		3,250,000
III.	Diking		30,000
IV.	Drift Boom		10,000
V.	Clearing & Grubbing		10,000
VI.	Site Acquisition		50,000
VII.	Cover Material		350,000
VIII.	Turf Establishment		180,000
IX.	Seeding & Mulching		20,000
X.	PCB Testing & Dredge Control		170,000
	Subtotal Without Treatment		$4,210,000
XI.	Treatment		
	Sedimentation & Coagulation		110,000
	Subtotal		$4,320,000
XII.	Contingencies @ 25%		1,080,000
XIII.	Engineering		389,000
XIV.	Legal & Administrative		86,000
	Total Including Treatment by Sedimentation & Coagulation		$5,875,000

COST ESTIMATE SUMMARY
REACH 6 (Continued)

	Subtotal Without Treatment	$4,210,000
XIB.	Treatment	
	Sedimentation & Coagulation	110,000
	Carbon Adsorption	500,000
	Subtotal	$4,820,000
XIIB.	Contingencies @ 25%	1,205,000
XIIIB.	Engineering	434,000
XIVB.	Legal & Administrative	96,000
	Total Including Treatment with Filtration - Adsorption	$6,555,000

COST ESTIMATE SUMMARY
REACH 7
LOCK 6 (RM 186.2) - THOMPSON ISLAND DAM (RM 188.5)

	Volume of Bed Material (Mil. Cubic Yards)		0.69
I.	Mobilization *		370,000
II.	Dredging		
	Clamshells 1 5.8 months		
	Operating	420,000	
	Ownership	170,000	
	Tugs 1 Tenders 1		
	Operating	400,000	
	Ownership	70,000	
	Scows 2		
	Operating	20,000	
	Ownership	140,000	
	Hopper-Conveyor Barge		
	Operating	130,000	
	Ownership	90,000	
	Rehandling Clamshell 1		
	Operating	160,000	
	Ownership	140,000	
	Prepare Rehandling Area	220,000	
	Loading, Hauling, & Spreading	1,720,000	
	Supervision & Engineering	60,000	
	Overhead & Profit @ 35%	1,310,000	
	Subtotal		5,050,000
III.	Diking		40,000
IV.	Drift Boom		10,000
V.	Clearing & Grubbing		10,000
VI.	Site Acquisition		70,000
VII.	Cover Material		500,000
VIII.	Turf Establishment		250,000
IX.	Seeding & Mulching		30,000
X.	PCB Testing & Dredge Control		230,000
	Subtotal Without Treatment		$6,560,000
XI.	Treatment		
	Sedimentation & Coagulation		220,000
	Subtotal		$6,780,000
XII.	Contingencies @ 25%		1,695,000
XIII.	Engineering		610,000
XIV.	Legal & Administrative		136,000
	Total Including Treatment by Sedimentation & Coagulation		$9,221,000

COST ESTIMATE SUMMARY
REACH 7 (Continued)

	Subtotal Without Treatment	$6,560,000
XIB.	Treatment	
	Sedimentation & Coagulation	220,000
	Carbon Adsorption	500,000
	Subtotal	$7,280,000
XIIB.	Contingencies @ 25%	1,820,000
XIIIB.	Engineering	655,000
XIVB.	Legal & Administrative	146,000
	Total Including Treatment with Filtration - Adsorption	$9,901,000

* Includes allowances for access to and from land-locked Lock 6 pool.

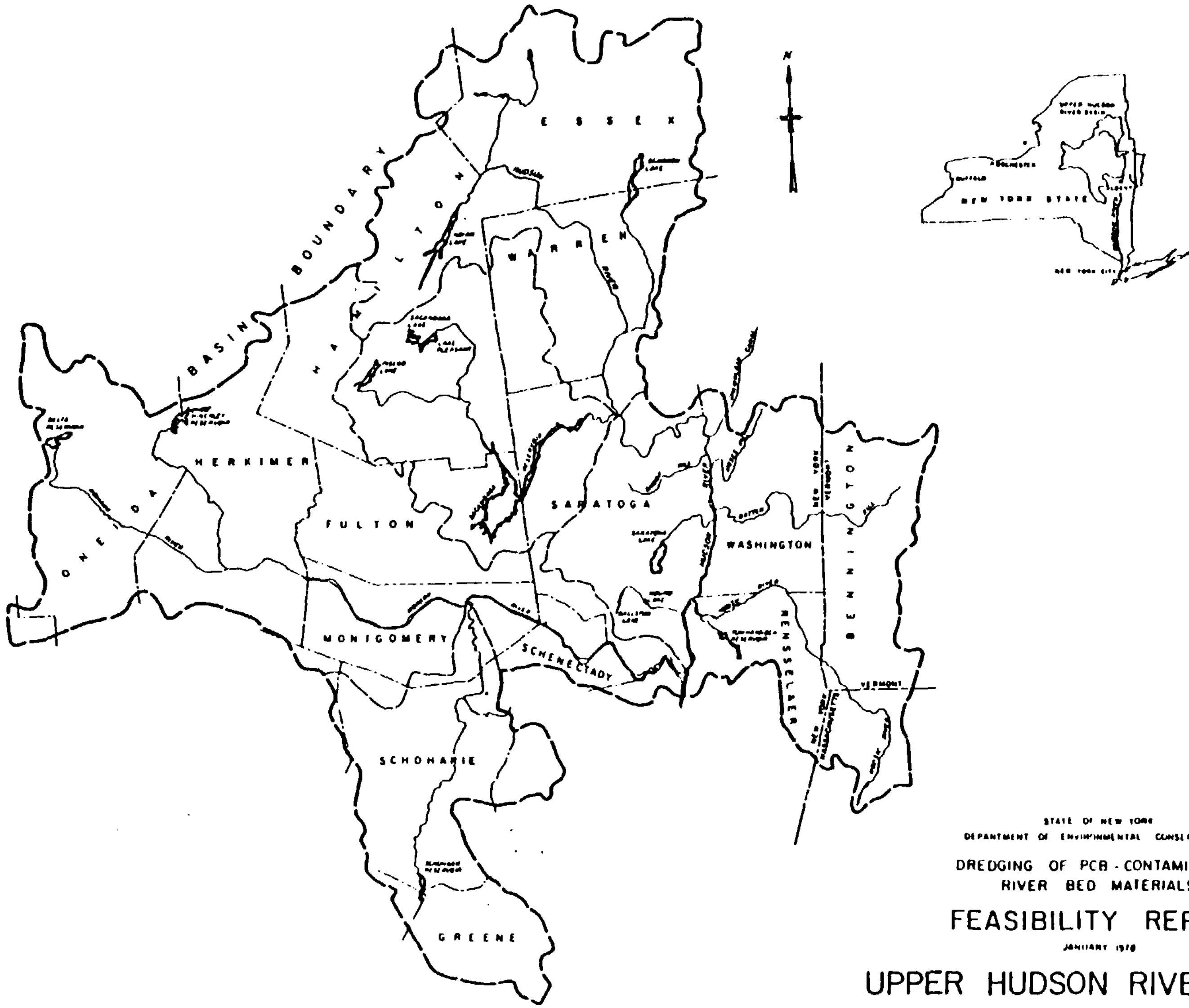
COST ESTIMATE SUMMARY
REACH 8
THOMPSON ISLAND DAM (RM 188.5) - LOCK 7 (RM 193.7)

	Volume of Bed Material (Mil. Cubic Yards)		0.50
I.	Mobilization		120,000
II.	Dredging		
	Clamshells 1 4.2 months		
	Operating	300,000	
	Ownership	120,000	
	Tugs 1 Tenders 1		
	Operating	290,000	
	Ownership	50,000	
	Scows 2		
	Operating	20,000	
	Ownership	100,000	
	Hopper-Conveyor Barge		
	Operating	110,000	
	Ownership	60,000	
	Rehandling Clamshell 1		
	Operating	110,000	
	Ownership	100,000	
	Prepare Rehandling Area	110,000	
	Loading, Hauling, & Spreading	1,000,000	
	Supervision & Engineering	40,000	
	Overhead & Profit @ 35%	840,000	
	Subtotal		3,240,000
III.	Diking		30,000
IV.	Drift Boom		10,000
V.	Clearing & Grubbing		10,000
VI.	Site Acquisition		50,000
VII.	Cover Material		360,000
VIII.	Turf Establishment		180,000
IX.	Seeding & Mulching		20,000
X.	PCB Testing & Dredge Control		190,000
	Subtotal Without Treatment		$4,210,000
XI.	Treatment		
	Sedimentation & Coagulation		110,000
	Subtotal		$4,320,000
XII.	Contingencies @ 25%		1,080,000
XIII.	Engineering		389,000
XIV.	Legal & Administrative		86,000
	Total Including Treatment by Sedimentation & Coagulation		$5,875,000

COST ESTIMATE SUMMARY
REACH 8 (Continued)

	Subtotal Without Treatment	$4,210,000
XIB.	Treatment	
	Sedimentation & Coagulation	110,000
	Carbon Adsorption	500,000
	Subtotal	$4,820,000
XIIB.	Contingencies @ 25%	1,205,000
XIIIB.	Engineering	434,000
XIVB.	Legal & Administrative	96,000
	Total Including Treatment with Filtration - Adsorption	$6,555,000

PLATES



STATE OF NEW YORK
DEPARTMENT OF ENVIRONMENTAL CONSERVATION

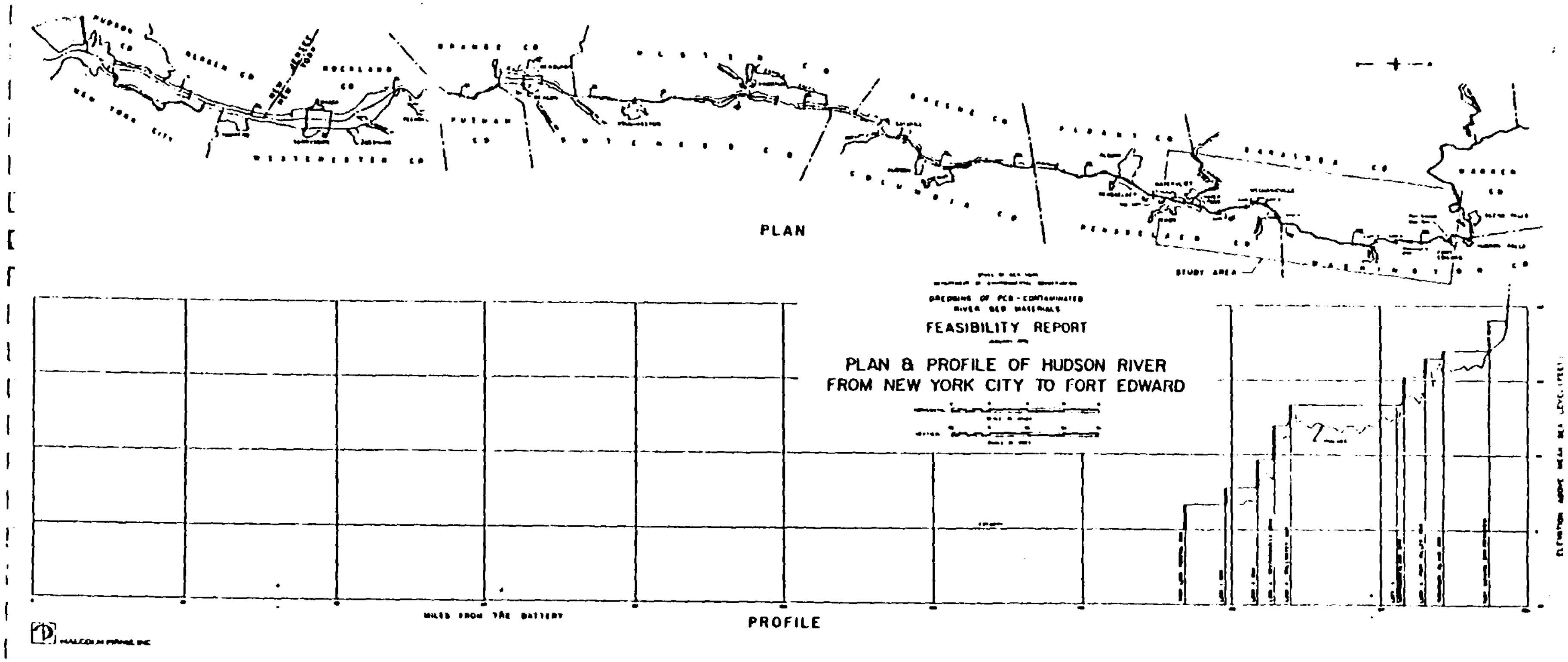
DREDGING OF PCB - CONTAMINATED
RIVER BED MATERIALS

FEASIBILITY REPORT

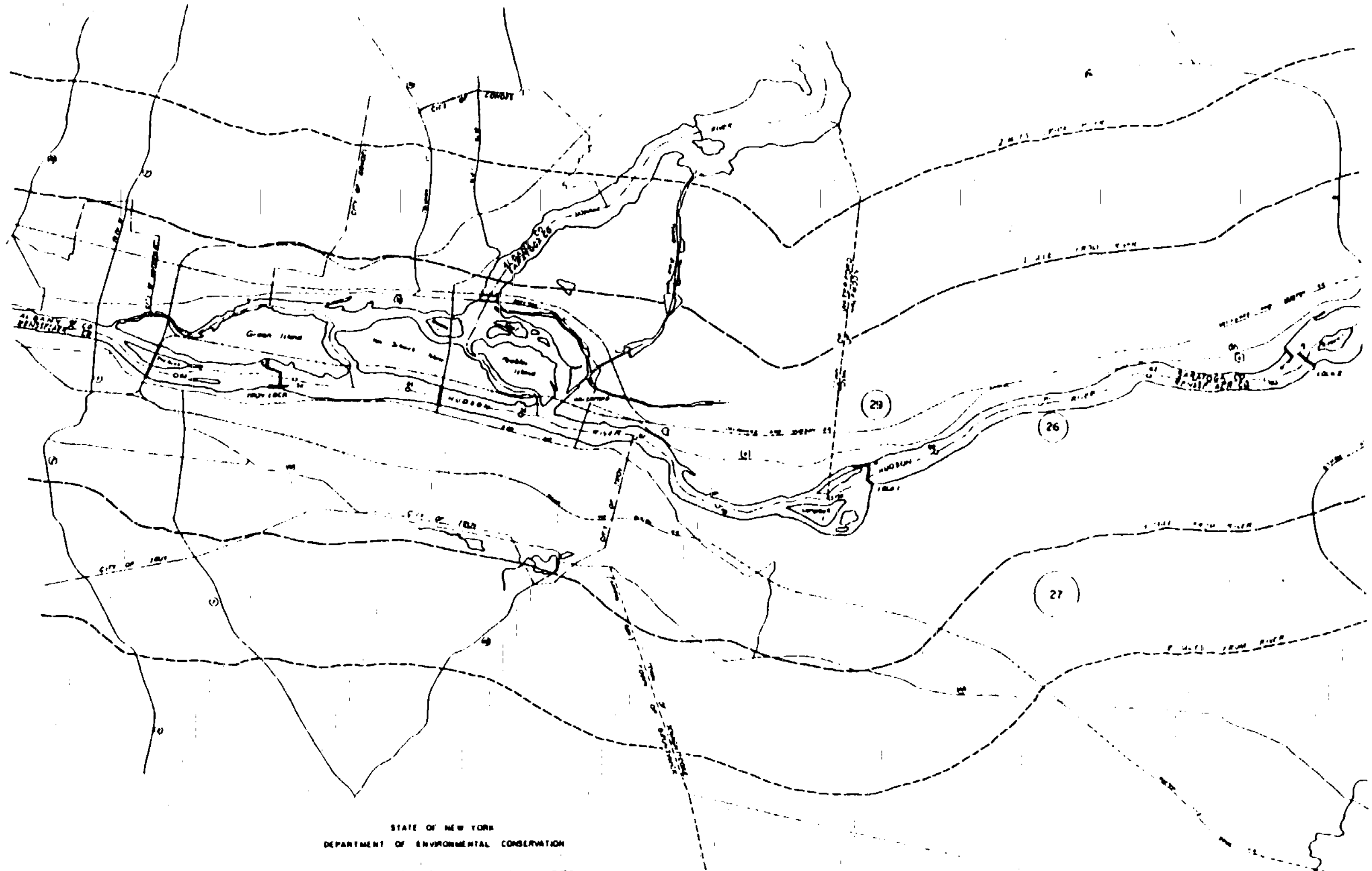
JANUARY 1978

UPPER HUDSON RIVER BASIN

MALCOLM PIRNIE INC



PLAN
DREDGING OF PCB-CONTAMINATED RIVER BED MATERIALS
FEASIBILITY REPORT
PLAN & PROFILE OF HUDSON RIVER
FROM NEW YORK CITY TO FORT EDWARD
STUDY AREA
MILES FROM THE BATTERY
PROFILE
MALCOLM PIRNIE INC



STATE OF NEW YORK
DEPARTMENT OF ENVIRONMENTAL CONSERVATION

DREDGING OF PCB – CONTAMINATED
RIVER BED MATERIALS

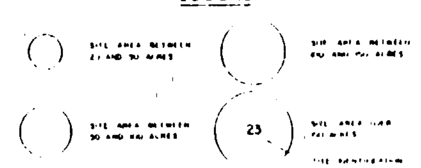
FEASIBILITY REPORT

JANUARY 1978

POTENTIAL DISPOSAL SITES

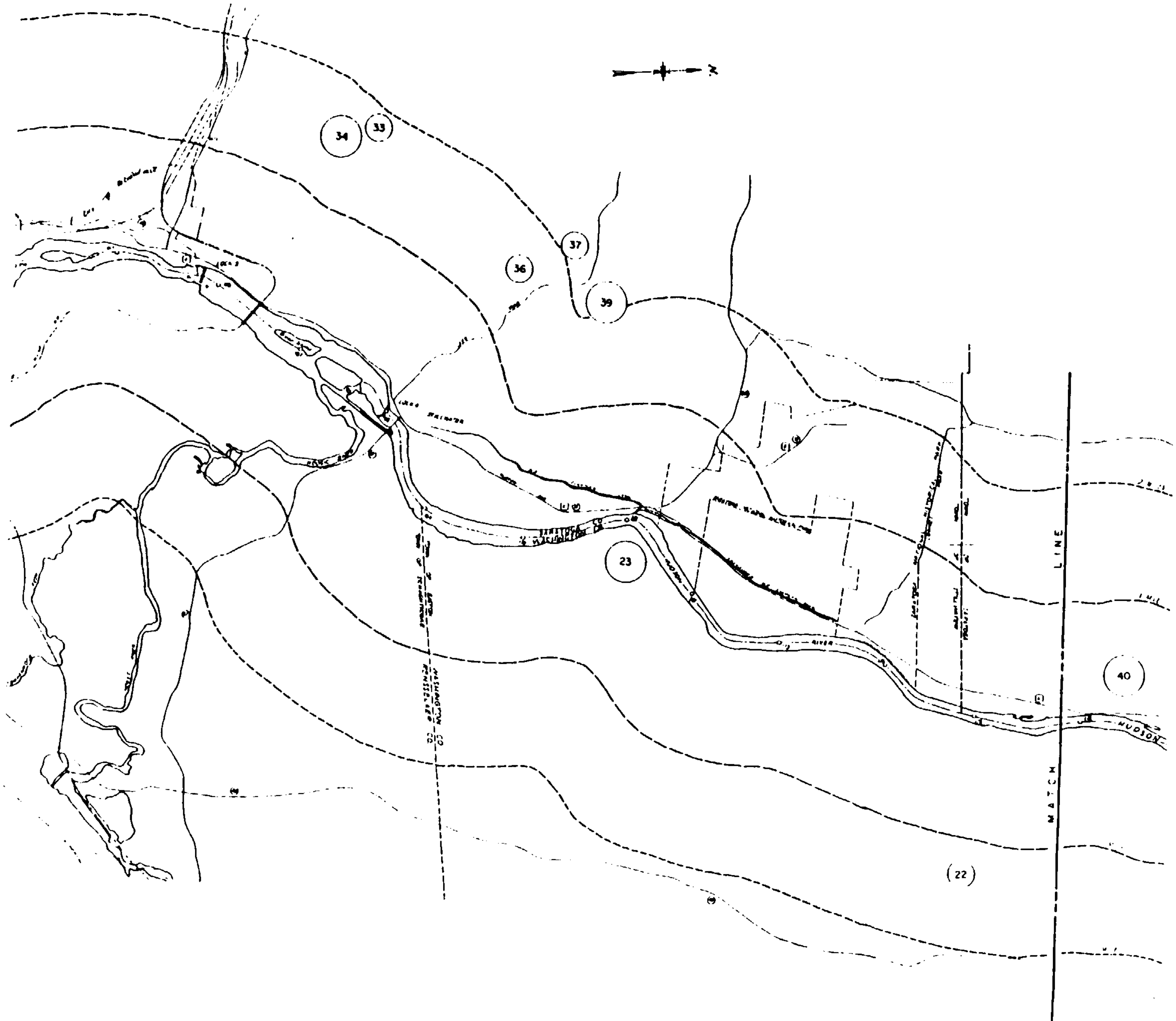
SCALE IN MILES

LEGEND



MALCOLM PIRNIE, INC.

PLATE III



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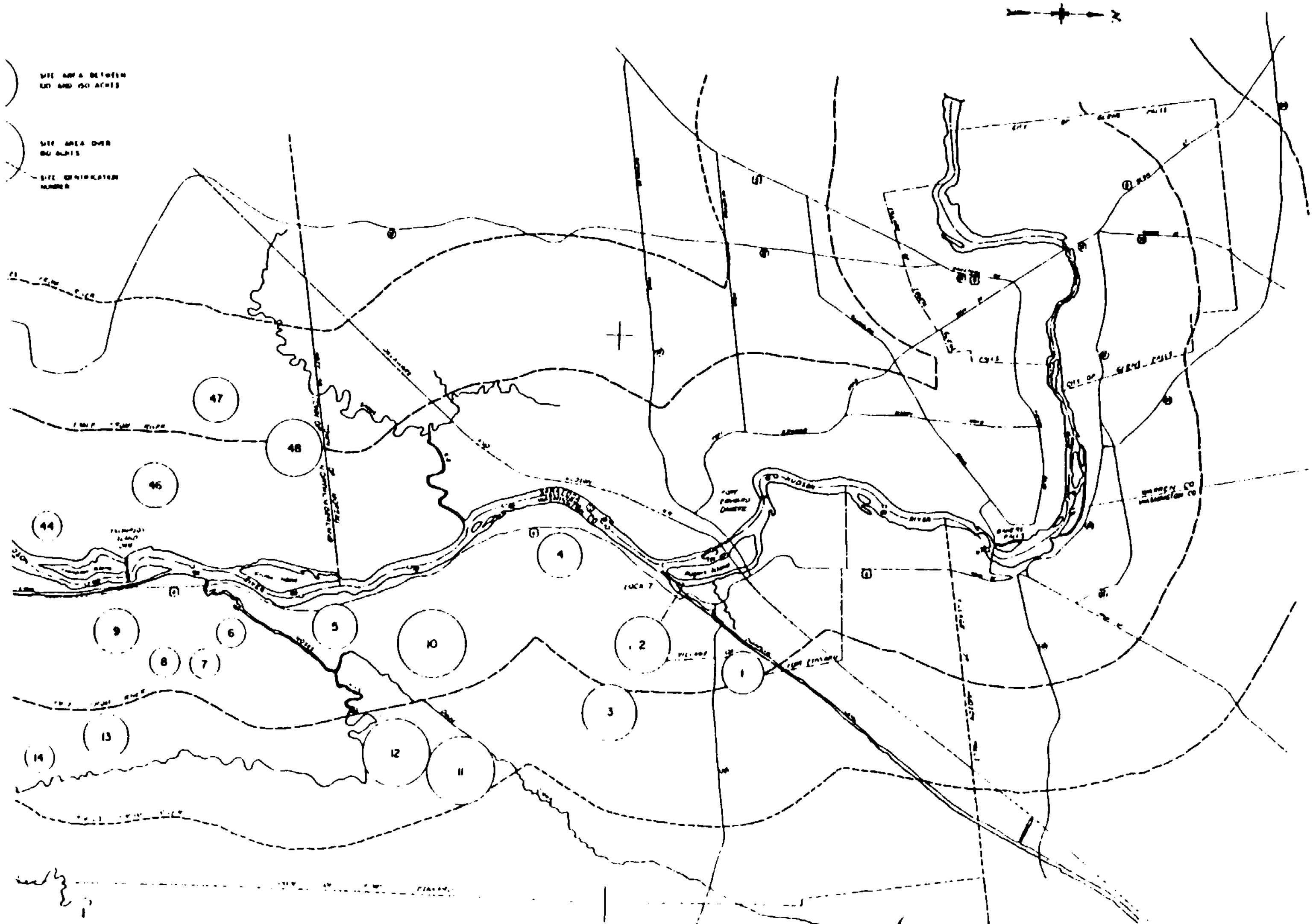
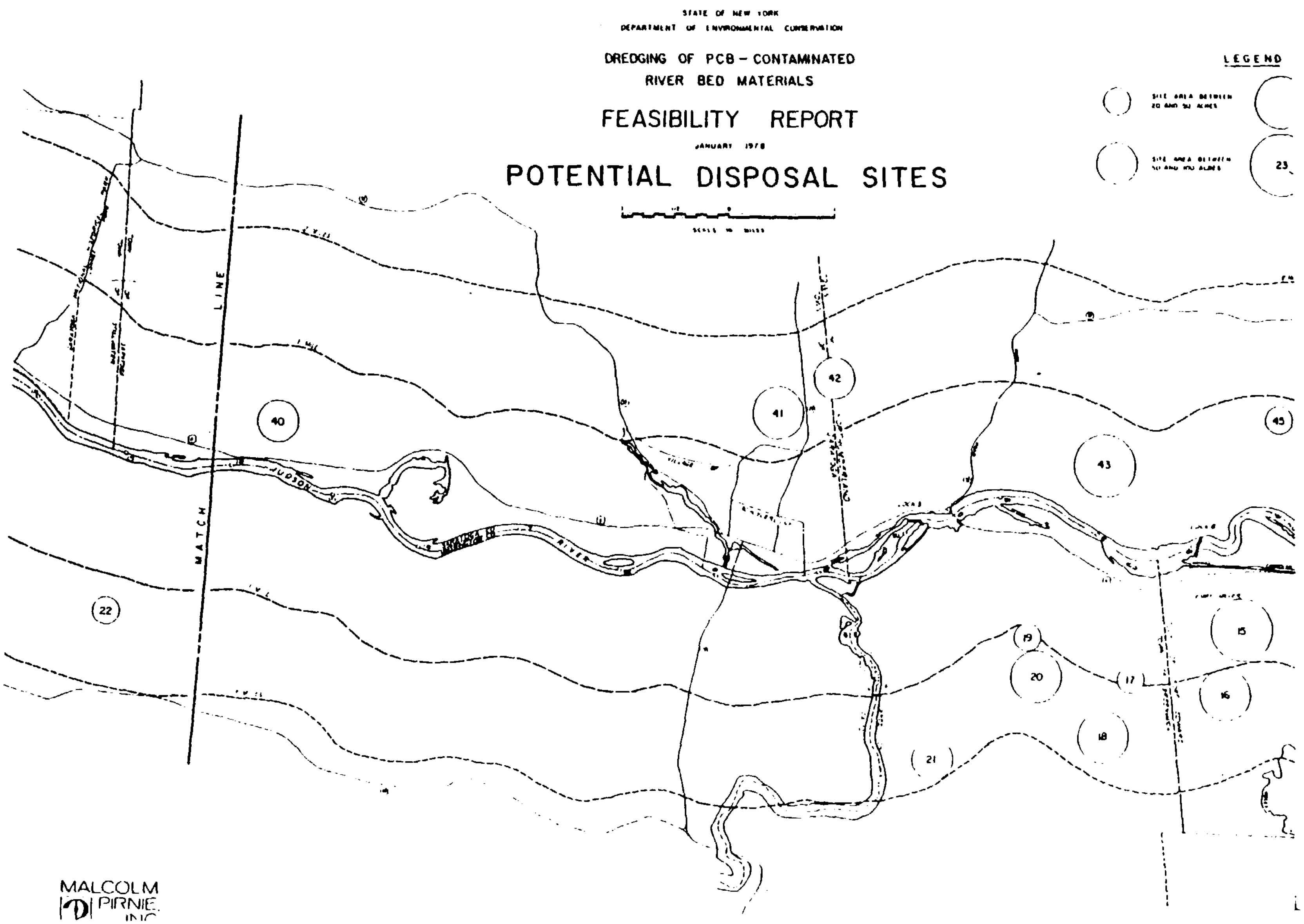
HUDSON
RIVER
MATCH LINE
WASHINGTON CO
RENSSELAER CO

PLATE IV





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